Tropical Products Institute

G137

Handbook for junior fisheries officers Part 1

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Overseas Development Administration

This report was produced by the Tropical Products Institute, a British Government organisation which co-operates with developing countries in helping them to derive greater benefit from their plant and animal resources. It specialises in post-harvest problems and will be pleased to answer requests for information and advice addressed to the Director.

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PLATES IN TEXT

PREFACE

This handbook is intended to give new recruits to Fisheries Departments, or students at Fisheries Training Centres, a basic introduction to the range of tasks they are likely to encounter in the course of their work. Most of the topics discussed are complex and we have attempted to present a brief overall review, highlighting the areas most likely to concern a practical field worker.

This report contains the first chapters of the handbook. The following Chapters will be published in a further part, or parts.

We wish to record our thanks to the many people who provided helpful comment, information and constructive criticism during the preparation of this report. The authors also wish to express their thanks to Gifford and Partners, Carlton House, Ringwood Road, Woodlands, Southampton, UK for the use of the photograph of 'Sandskipper' in Plate 1. Similarly to MacAlister Elliott and Partners Ltd, 6 Highfield, Lymington, Hampshire SO4 9GB, England, for the sequence of photographs for Plate 2. And finally to Windboats Marine Limited, Port of Wroxham, Wroxham, Norwich, Norfolk NR12 8RX, England, for the photographs in Plate 3.

Introduction

Fisheries departments exist in most developing countries of the tropics. In these countries fish are often the most important source of animal protein for large sectors of the population. At higher levels these Fisheries Departments are staffed by graduates, many of whom have received specialised training outside their own country. These men are few in number and most of them are responsible for the development of the fisheries of relatively large areas.

At the lower levels field staff are often recruited straight from school and they enter Departments in small numbers at any one time. To provide any sort of training at all for these people is difficult, particularly in smaller countries, and training often has to be left to senior officers, already busy with other tasks. Within a short time of joining the Department the young recruit is likely to find himself the sole representative of that Department in a community of fishermen, all of whom inevitably know more about the day to day business of the fishing industry than he does himself. The recruit's first task is, therefore, to learn as much as he can about the activity of the local fishermen, fish processors and salesmen. He can only do this if he can talk to them with understanding and gain their confidence.

This handbook has been written with the intention of providing some elementary information about fishing industries generally, and is, in fact, intended as a primer or first reader for new recruits. No text can be a substitute for practical experience and most of the information which the new recruit requires will come from people within the industry. This is an attempt to help him understand what he hears and to tell him where more detailed information can be found.

Little in this report is new or original and it is in fact largely a guide to further reading. Very few references have been made to scientific papers since these are unlikely to be available to the average reader and would not in some cases be easily understood. In most chapters an attempt has been made to refer the reader to books and reports which expand the information given here. These books will be available in most fisheries Departments or certainly should be.

Many countries have benefited from the advice given by specialists who have worked for the Food and Agricultural Organization (FAO) of the United Nations (UN) on assignments under the various programmes of technical cooperation. When such experts complete an assignment they prepare a Report. The Reports which refer to the area in which recruits are to work should obviously be compulsory reading since the advice given can often form the basis of the recruit's own efforts. Advisers from developed countries also carry out technical cooperation projects and their reports should also be studied.

A number of tables, conversion factors, etc., have also been included, these are in an Appendix at the end of the report rather than in the text so as to be more easily found when needed.

Chapter 1

The work of a fisheries department

In most developing countries of the tropics much of the fishing industry is still at a peasant level. Fishing is regarded as a humble occupation, boats and fishing gears are small and primitive and processing methods are crude. These factors limit the productivity of these industries, in many cases the individual fisherman only catches one or two tons of fish a year; he cannot fish far from his home because his boat is too small and his fishing gear is designed for use in shallow water. If he spends too long at sea his catch goes bad before he can market it and even if he does land an unusually good catch, he may be unable to sell it at a profit. Unable to sell it because no system for marketing exists which would enable the fish to be carried inland to places where possible buyers live.

In spite of what has been said about the level of these fishing industries, it must not be assumed that the fishermen are either ignorant or foolish. In many cases they have an immense fund of traditional local knowledge and the methods they are using have stood the test of time. It must not be assumed that a 'modern' or 'western' method is necessarily superior, it must be proved to be better in every case before it is adopted. Many experienced, skilful fishermen who have been very successful on their home grounds, have found that they needed to start by acquiring local knowledge before they could advise and help fishermen of the tropics to improve their methods. A blend of local knowledge and an understanding of modern techniques is required.

In many cases quite simple improvements to the boats or fishing gears can enable the fisherman to increase his catches. A motor sometimes enables him to fish in places he could not reach by sailing or paddling, and bring back his catch in an edible condition when it would otherwise spoil. If he can carry ice, or salt his fish at sea, he might be able to spend longer at sea, catch more fish and land it in a better condition. Simple though these improvements are, their introduction is expensive and often involves added complications which alter the way of life of a number of people other than the fishermen.

To take one simple case, the introduction of outboard motors. First, the capital cost; an outboard motor may cost more than both the boat and fishing gear that the fisherman already owns. It may therefore be necessary to lend him the money to buy it, so the first complication is a loan scheme which must ensure that only the efficient fishermen get loans and that they repay them. Direct grants are a possible alternative that does not involve the problem of ensuring repayment of a loan by a fisherman. (In some developing countries it has proved very difficult to persuade the fishermen to repay loans). In the case of direct grants, the Department gives a proportion (e.g. 33% or 50%) of the cost, when the fisherman shows that he has the balance in cash.

The boat may require modification before the engine can be fitted, this requires experimentation to find the best method of modifying it and then demonstrations to show local boat builders how to do it. The fisherman must be taught how to operate

his engine, if this is not done he may spoil it very quickly. Even the best engines break down occasionally and need repairing, someone must be taught to carry out these repairs. Also someone must be persuaded to keep stocks of spare parts in a place where they are quickly available when needed. Fuel supplies must be arranged for. On top of all this, the fisherman must catch more fish than he did without the engine, to pay for both the engine and the fuel he is using, and for its repair and eventual replacement. If he does not catch more fish he will be worse off than before, he may even have to catch two or three times as much fish as he did without the engine. Obviously before a loan scheme is started a lot of work and careful calculation is need if the introduction of motors is to be successful. We shall return to some of these points in later chapters.

Fisheries Departments are branches of Government, this means among other things, that the money which pays the staff wages and buys the equipment used by the staff is public money collected from the people in the form of taxes. The members of the staff are, therefore, public servants, and their duty is to provide a public service. In this case the service is the control and development of the fishing industry. What should the aim of the service be? Different members of the community would give very different answers to this question. The housewife might say that it is to 'provide more fish, or cheaper fish, or fish of better quality, or a wider variety of fish'. The fisherman might say, 'to help us to catch more fish and earn more money, teach us new ways to catch fish or improve our living conditions.' The Government might say 'we are spending too much money on importing fish, we must catch more ourselves and reduce our foreign expenditure, or we must export more and earn more foreign currency to buy other things we need.' There may be a need to increase employment in the industry and provide more jobs for an increasing population.

Sometimes these aims may seem to be in conflict, for instance, the housewife's desire for cheaper fish and the fisherman's desire to get more money for his efforts. However, the first aim of the Department is usually to provide the country with sufficient fish to meet the need for food and to see that it is available at a price people can afford to pay. At the same time it is the aim to see that fishermen and others connected to the industry have an opportunity to earn a reasonable living.

A great many different skills are required to meet these varied aims, scientific research may be needed to discover where additional supplies of fish may be found and how much fish may be caught without reducing the amount likely to be available in the future. Such research may be the responsibility of the Fisheries Department, or alternatively of a separate research organisation working closely with the Department. There must be experiments to decide how best to catch the fish and how best to preserve it so that it reaches the market in good condition. There must also be an extension service to teach fishermen and other people associated with the industry how to apply new techniques; one or more training schools may be needed. Usually it is necessary to pass laws to control some of the activities of the fishermen to ensure a proper exploitation of the resources and to prevent disputes. An inspection and control service may be needed to enforce these controls. Before any of these services can be set up we need to know what we are talking about when we refer to the 'fishing industry'. How many people are involved? Where do they live? What boats and fishing gears exist? Where and when is the fish caught? How is it preserved and marketed? What seasonal variations exist in all these factors? The answers will lead to a further set of questions such as, who owns the equipment used? How do catches and prices vary throughout the year? How much does a fisherman using a particular set of equipment earn in a year? What are his costs?

The first essential function of any Fisheries Department should obviously be to answer these questions and to prepare a catalogue showing the capital resources in terms of people and equipment available and how these are distributed. The second function is to show what use is made of the equipment and what it produces. These functions involve the collection of statistics.

THE COLLECTION AND USE OF STATISTICS

A statistic is simply a number, for example it might be the number of fishermen in a country or village, the number of drift net fishermen or handliners in the village, or the number of drift net fishermen who own their own boats. Each of these numbers would provide some information but each would provide quite different information. If you are collecting statistics, or numbers, you must be quite sure you understand what statistics are wanted. Collection of statistics takes time and therefore costs money. The more detailed the figures the more it costs to collect them and the more time that must be spent in sorting them out and analysing them.

The amount of detail required varies for different purposes, if you want to know the average catch by a fisherman of the country in one year, you need only know how much fish was caught and how many fishermen there were. But even the collection of these figures can occupy a lot of time. The number of fishermen might be obtained by making one check during the year, but the total quantity of fish caught can only be obtained by making regular enquiries from a lot of people in a lot of places and adding the answers together. If this average 'catch per fisherman', is known for a number of years' you can see at a glance whether the average is increasing, decreasing or static over the years. This is useful information for if you know what changes have occurred in the industry you can begin to see what effect these have had on the industry as a whole. If you also know the value of the catch you can make an estimate of the average income of the fishermen.

But, at this point, we must note how misleading such statistics can be. For instance, the introduction of a small number of large trawlers, where only canoe fishermen worked previously. Each crew member of the trawler would catch several hundred times as much fish as a canoe fisherman, and the resultant figures might make it appear as if every fisherman was better off. In fact, if more fish were landed and the average price fell the canoe fisherman might be very much worse off than before. In this case we should record the trawlers' landings separately from those by other fishermen.

Averages can be useful since they give an idea of the middle point of a set of figures, when we talk of averages we usually refer to the **arithmetic average** or **mean,** that is the total divided by the number of samples. Thus if eight fishermen caught 200, 120, 100, 100, 100, 80, 60 and 40 kg of fish in a week the average or mean catch would be 100 kg. Only three men actually caught 100 kg, one man caught twice as much and one man caught only 40% of this average. If in addition to giving the average we state the top and bottom catches, this would give the **range.** That is, catches range from 40 kg to 200 kg with an average of 100 kg. We may alternatively give the figure which occurs most frequently, in this case also 100 kg. This is the **modal value.** Another figure we might take is the actual middle figure or **median** in this case also 100 kg. Usually range and arithmetic average figures are used in fisheries statistics; the modal value and median are close to the mean in most cases. In many cases we need more detailed information than that suggested in our first example, statistics taken over the whole country would not tell us how different groups of fishermen have done during the year. If we want to know the income of the drift net fishermen and line fishermen we must record their catches separately and if we want to know the quantities of fish of different species that were caught, these must be recorded separately for each boat or fisherman.

In countries with modern fishing industries where relatively few large vessels land huge quantities of fish it is easy to collect full statistics of this kind. The captains and owners maintain their own records and can easily give this information, the scale and value of the industry are such that the countries can afford to employ people to collect and analyse this information. In developing countries there are often thousands of small boats from which catches are landed at frequent intervals in isolated places. The fishermen keep few or no records and some may be illiterate. In these circumstances the collection of full records is impossible, it would take too long, cost too much and provide too much information for analysis by the limited numbers

of staff available. We must, therefore, decide what information we most need and then how best to obtain it.

Some of the most important information can be obtained by making an annual survey. By visiting every village or fishing station once a year, we can record the facts which alter little from year to year, for instance, numbers of fishermen, boats of different types, gears of different types, fishing camps, factories and so on. Where boats or fishing gears are licensed and registered, the registers would provide much information (Figure 1).

Figure 1a

Specimen survey form

FRAME SURVEY

Name of the Recorder ______________ C.No. of Fishing Site [ ] [ ]

Survey date [ ] [ ] [ ]

ITEMS OF INFORMATION	
1. Identification particulars of the fishing site	1. Name(s) of the fishing site: 2. Tribe(s) of fishermen: [ ]
2. Organic structure of the fishing site	(ASK): 1. Is the occupation of the fishing site by the fishermen: continuous [ ] 1 sporadic [ ] 2 2. Are the fishermen of the fishing site: permanent [ ] 1 transient [ ] 2
3. Migration history	(ASK): 1. When did they first commence fishing on the lake? ______ [ ] 2. Before the formation of the lake were they: 1. Fishermen [ ] Number; where ______ [ ]; remarks: 2. Farmers [ ] Number; where ______ [ ]; remarks: 3. Other [ ] Number; where ______ [ ]; remarks: (ASK): 3. When did they come to the present place? ______ [ ] 4. Where were they staying before they arrived in this place? 4.1 Name of the place ______ 4.2 What kind of place was it? ______ [ ] 4.3 Where was it located? ______ [ ] 5. How long did they stay in the previous place? ______ [ ] 6. Do they intend to move again? Yes [ ] 1 No [ ] 2 6.1 If YES: 1. why? ______ [ ] 2. when? ______ [ ] 3. where? ______ [ ] General remarks on page 1 of the Form:

Figure 1b

Specimen survey form (contd)

Survey date | | |

C.No. | |

4. Fishing periods: (experience of the last year)	(ASK): 1. Do they fish all the year round? Yes [ ] 1 No [ ] 2 1.1 If NO, during which period(s) do they fish? 1. period: from to 2. period: from to
5. Fishing gear used: (experience of the last year)	(ASK): What kind of gear do they use for fishing (complete the following table):

Gear		Period used	Remarks
C.No.	Name (1)	(2)	(3)
01		from to	
02		from to	
03		from to	
04		from to	
05		from to	

6. Fishing boats, fishermen [local fishing boats which were absent on the survey day (e.g. fishing, at market) must be included in the table]

(ASK): Complete the following table:

1. Fishing boats by kind:			2. Number of fishermen		Remarks
C.No.	Name (1)	Number (2)	Owners (3)	Assistants (4)	
01	Canoes				
02	Plank boats (without engine)				
03					
04					
05					

09 Number of fishermen without fishing boat working for themselves ______

General remarks on page 2 of the Form:

Figure 1c

Specimen survey form (contd)

Survey date [ ] [ ] [ ]   C.No. [ ] [ ]

7. Fish catch; (insert a √ in the proper box(es))

(ASK): Fish mainly caught:

1. Tilapia [ ]
2. Alestes [ ]
3. [ ]
4. [ ]

8. Disposition of fish catch: (insert a √ in the proper box(es))

(ASK): 1. Complete the following table:

Marketed state of fish:		Disposition of fish catch:			
C.No.	Name (1)	Total (2)	Almost total (3)	About half (4)	Less than half (5)
1	Fresh				
2	Smoked				
3					
4					
5					

(ASK): 2. Do fish traders come to the place? Yes [ ] 1 No [ ] 2

2.1 If YES:

1. How ______________________ [ ]
2. How often ______________________ [ ]
3. From where ______________________ [ ]

3. Do fishermen (or wives etc) go to market in order to dispose of their catches? Yes [ ] 1 No [ ] 2

3.1 If YES:

1. How ______________________ [ ]
2. Where ______________________ [ ]

9. Capital goods supply centers

(ASK): 1. From where do they buy their canoes ______________________ [ ]

1.1 Usual purchased value of a new canoe ______________________

2. From where do they buy their gears ______________________ [ ]

2.1 Complete the following table:

Gear		Unit	Price per unit	Remarks
C.No.	Name			
	(1)	(2)	(3)	
01				
02				
03				
04				
05				

General remarks on page 3 of Form:

Source: Bazigos, 1974

It is the statistics for catches and the values of these which are most difficult to obtain, especially where the catch is not weighed before it is sold. In circumstances like these, it would be impossible to obtain accurate information by making occasional visits and asking people to remember what happened weeks or months ago, regular visits must be made at short intervals and spot checks made to see whether these tally with the information given. If fish is sold by the bundle, string, or kerosine tin full, these units can be weighed at intervals so that they may be converted to weights. Where most of the local catch passes through one market, arrangements may be made for records to be kept there.

The method used for recording catches or landings may vary from one part of the country to another, or one type of fishing unit to another. It may be possible to record the catches of all the larger units but impossible to do this with the smaller, more numerous, units. Where it is impossible to keep records for all the boats, records can be kept for some and these used to give averages and estimated totals. The recording of results from a number of units is called **sampling** and the units from which records are made the **sample.** The sample should be selected at random, that is, by avoiding the deliberate selection of the best or worst boats in the fleet, or, more particularly of those kept nearest to a convenient point. For instance a random sample can be selected by taking every fifth or tenth boat in the boat register, by walking along the beach and taking every fifth or tenth boat or, by putting all the owners' names in a hat and drawing the required number. It would, for example, not be right to select only from the fishermen who are literate and can keep records. These might be the most intelligent and best fishermen, or come from richer families and so own the best boats and gears. Once a sample has been selected the same sample should be investigated each time figures are collected. If this is not done the records become meaningless. If, for instance, you are sampling landings from ten boats, it is no use collecting figures from any ten boats which went to sea. A sample of ten boats should be selected and when some of these do not go to sea the fact should be noted because this is an important part of the way in which the industry functions. If some boats are not at sea there must be a reason for this and it is important to our understanding of the industry to know how frequently the boats put to sea and the reasons for their not doing so.

Care must be taken to see that differences between the fishing units are accounted for, for instance, if some boats of a handline fleet carry only four men and others five or six, it would be better to record the catch per man rather than the catch per boat. If some boats carry twenty and others forty pieces of drift net, this should be noted, as some boats would be expected to catch twice as much as others. If some boats are using nets with meshes of different sizes, or made from different materials, they should not be placed in the same sample, as these factors could make a great difference to the catches. It all depends on how much information is needed. If we are only interested in the total catch, we might add all these figures together, if we are interested in the differences in the way fish is being caught, then we must record as much information as possible.

Ideally, statistics for catches and values should be recorded every day, often this is not possible and weekly or even monthly visits must be made; the shorter the interval the better. The information collected is usually entered on a standard form supplied to all the staff who are required to obtain facts about the district. These forms must be completed regularly and as accurately as possible if the information they contain is to be of maximum value.

If accurate records of the weights and values of the fish caught by different fishing gears can be obtained for the year, it is easy to find out how much fish was caught by each type of gear, in each part of the country. It is also possible to see how catches by each gear varied for different seasons and to work out the gross income of each fishing village or each fisherman.

Before we can calculate the actual net income per individual fisherman or boat owner, we need to know a number of other facts about the industry. These would include facts such as the cost of buying boats and gears and of maintaining them,

Figure 2

Specimen form for recording fishing units

<u>LIST OF EXISTING FISHING ECONOMIC UNITS</u>

Name of the Recorder ______________________ ☐

Survey date ☐☐☐

Sample fishing site — C. No. ☐ — Name ______________

FEU's	FISHING METHOD		FISHING BOAT		CREW					Remarks
	Prim	Other	Type	Reg. No.	Total	Boat owner	Crew leader	Assis-tants	Other (specify)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

Source: Bazigos, 1974

Figure 3a

Specimen form for catch record

CATCH RECORDS
(LUSENGA, BEACH DAGAA, LIFTNETS: 1, 3, 5)

Name of the Recorder ______________ [ ]   Selected FEU: C. No. [| |]

Landing date [| |]   Name of fishing site ______________

1. Particulars of fishing unit	(ASK): Complete the following table:											
	A. Fishing boat		B. Crew					C. Gear				Remarks
								Nets		Other		
	Reg. No. (1)	Type (2)	Total (3)	Boat owner (4)	Crew leader (5)	Asst (6)	Other (spec.) (7)	Kind (8)	No. (9)	Kind (10)	No. (11)	(12)

2. Fishing operation

(ASK): Time: 1. Started: 2. Completed:

3. Number of hauls:

4. Did your boat pick up other boat(s) catches?

Yes [ ] 1   No [ ] 2

3. Fish Catch							4. Fish Sold			
		Boxes		Baskets			Quantity			Remarks
Species (1)	Weight kg (2)	Size (3)	No. (4)	Size (5)	No. (6)	No. of fish (7)	Unit of measure (8)	No. of units (9)	Shs/ Unit (10)	(11)
01.0 Dagaa										
02.0 Mikebuka (Luciolates)										
03.0 Lates										
99.9 Other fish										

Sizes of boxes/or baskets: 1 = small size 2 = medium size 3 = large size

Figure 3b

Specimen form for catch record (contd)

CATCH RECORDS
OTHER FISHING METHODS

Name of the Recorder ______________________ [ ]

Selected FEU: C. No. [| |]

Landing date [| |]

Name of fishing site ______________

1. Particulars of fishing unit	(ASK): Complete the following table:							Remarks (8)
	A. Fishing boat		B. Crew					
	Reg. No. (1)	Kind (2)	Total (3)	Boat owner (4)	Crew leader (5)	Assis-tants (6)	Other (spec.) (7)	

2. Fishing operation	
	(ASK): Time: 1. Started: 2. Completed:
	3. Number of hauls (for beach-fish):
	4. Did your boat pick up other boat(s) catches?
	Yes [ ] 1 No [ ] 2

3. Number of fishing gear used	2. Gillnet		4. Beach-fish		6. Handlines		7. Other (specify)	Remarks
	1. Mesh size		Mesh size	No.	No. HL	No. Ho.		
	2. No. of nets							

4. Fish catch								5. Fish Sold			
Species		Weight kg	Boxes		Baskets		Number of fish	Quantity		Shs/ Unit	Remarks
C. No. (1)	Name (2)	(3)	Size (4)	No. (5)	Size (6)	No. (7)	(8)	Unit of measure (9)	No. of units (10)	(11)	(12)

Sizes of boxes/or baskets: 1 = small size 2 = medium size 3 = large size

Source: Bazigos, 1974

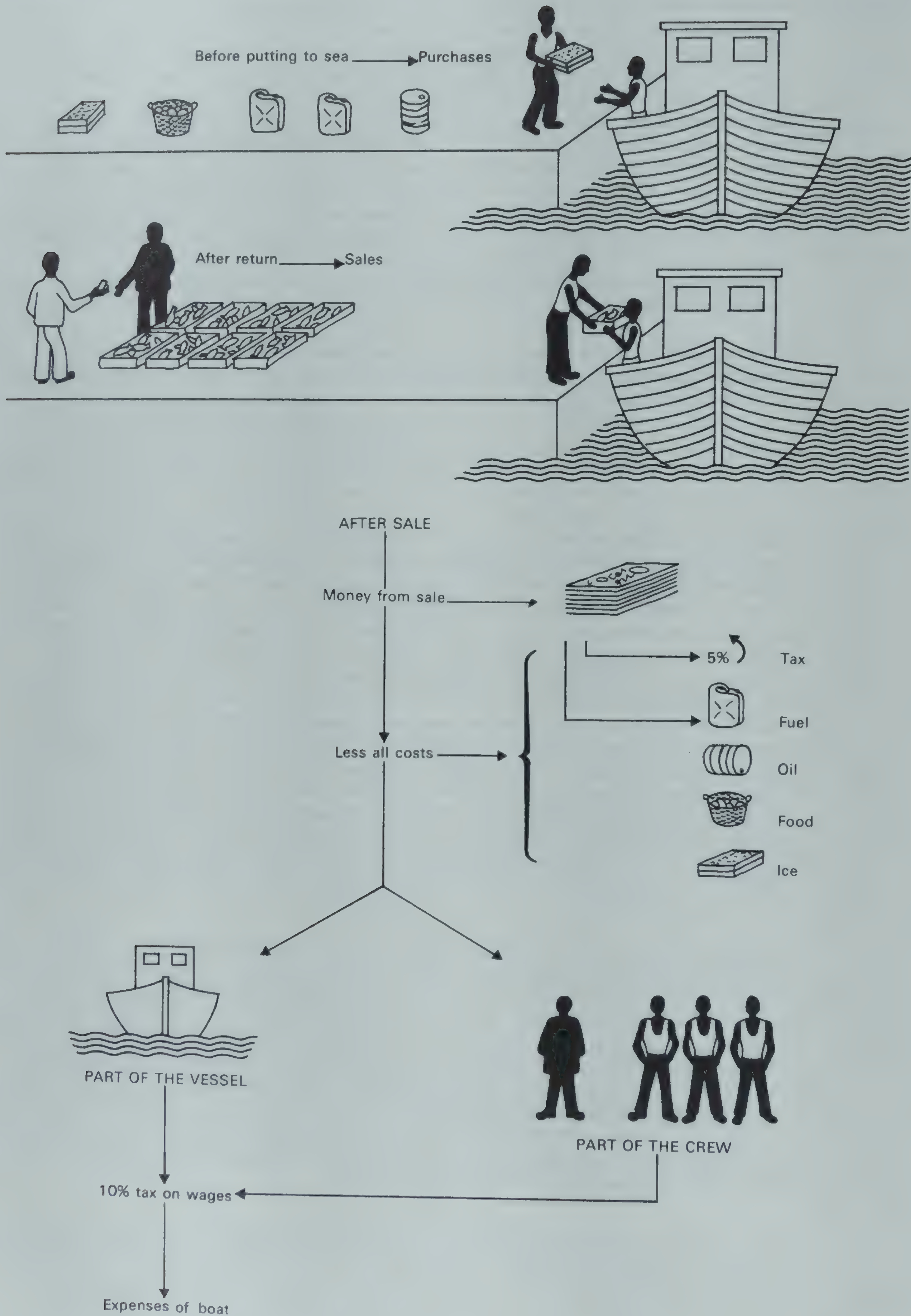
and also how the income is shared between the owner and his crew. Taking the simplest case first, that of a crew member who owns no equipment and works on someone else's boat. Very rarely is such a man paid a fixed wage, usually his income is a share of the money obtained from the sale of the catch, the amount of the share varies from one type of fishing to another and customs are different in different areas. In the simplest kind of share system, one share is given to the boat owner, one to the net owner and one to each crew member. A member of a three man crew would receive one fifth of the value of the catch under this system. Various deductions may be made before sharing, sometimes each crew member is entitled to take fish for his own family use and sometimes fuel and ice expenses are shared equally by the owner and crew, these are deducted before sharing. Some share systems are much more complicated than this, for instance, in large units the owner of the boat and fishing gear may take half of the proceeds, the remainder being divided between a crew of thirty or forty people. Some of these will receive one share, others two shares, some will receive additional half shares for tasks such as bailing the boat, waking the fishing crew, mending the nets, cooking while the boat is at sea and so on.

The calculation of the return to a boat or gear owner is inevitably more complex, while his share of the income is calculated in a similar way to that of a crew member his expenses in financing the operation must be obtained from financial records (accounts), or calculated for him. Very few such boat owners operate in a business like manner, that is to say, they do not cost their operations properly. When asked how much they spend a year on the maintenance of their boats and nets they do not know, nor do they know how long a boat or net will last before it needs replacement. If we were trying to calculate if it would be worthwhile putting an engine in a boat, replacing a cotton net with a nylon one or modifying the boat so that ice could be carried, we would need to know what it costs to operate the existing unit. We would also need to know how much fish each unit catches, how the fish is sold, and what price is fetched. If the change we are going to make is going to increase the owners operating expenses, and usually it will, we have to try to estimate whether or not the modified unit is likely to show an increased profit over the existing unit. Usually this can only be achieved if the new unit can catch more fish than the old. However an increased profit might be obtained in other ways, for example, a synthetic net lasts so much longer than a cotton one that it is cheaper in the long run to use one synthetic net rather than several cotton ones. In another example, better prices can be obtained by landing fish in a better condition by using either an engine, or ice. Figures 4 and 5 illustrate many of the items that need to be considered in accounting for the operation of a fishing boat. The figures have been taken from a publication of the Food and Agricultural Organization of the United Nations (Laxenaire, 1973). All fisheries students and extension workers are recommended to read this publication which clearly explains the principles of accounting and suggests methods for use by small-scale fishermen.

Some of the information needed should be available from the statistics recorded by the Department, for example, the average catch by the fishing units. Some of the facts that we need to know, such as the costs of repair and maintenance, may never have been needed previously. To discover these unknown, or rather unrecorded facts, a special investigation or **survey** is done. Some of the information about the probable costs of operating the new unit can be estimated quite accurately as, for example, the cost of buying and fitting an engine, and the amount of fuel it would use. Some of the other costs cannot be estimated with any great accuracy. Only when the unit is used for a number of years will it be possible to be sure of the costs of maintenance and repair, and it may take even longer to discover the length of time various items last before they wear out and have to be replaced.

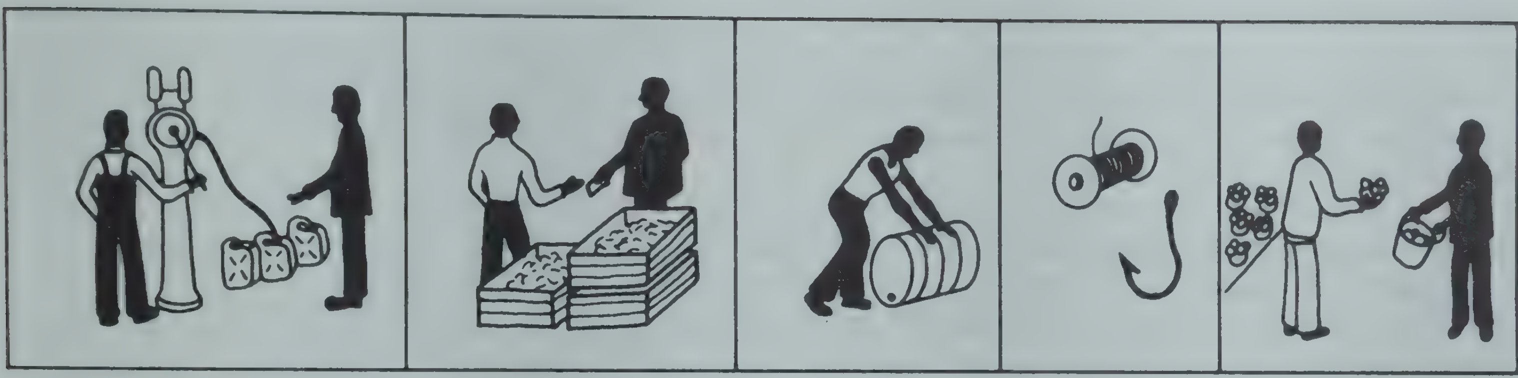
Having made careful estimations of the cost, the next step should be to start a **pilot project.** A pilot is a guide and a pilot project is intended to act as a guide for future development. Usually arrangements are made to provide an experienced fisherman with new equipment and to record the results he obtains with it. It is obviously important that full records of the results of pilot projects and trials should be kept for comparison with results recorded by fishermen not taking part in the experiments. Only then does it become possible to decide how and why a scheme has succeeded

Figure 4
Expenses and income of boat operation



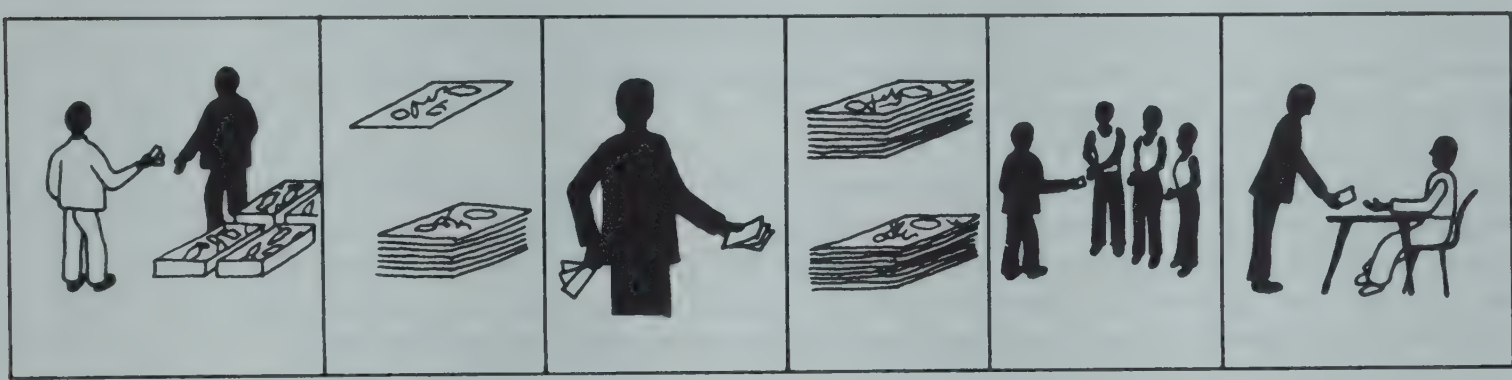
Source: Laxenaire FAO 1973

Figure 5
An example of how to calculate the expenses and income of boat operation



Before sailing he buys 150 worth of fuel | He then buys 20 worth of ice | He also buys 50 worth of oil for the engine | And 30 worth of material | And 60 worth of food

He then puts to sea



On return, he sells fish for 1000 | 5% amounting to 50, is withheld from him | From the remainder 950, he deducts expenses before sailing: 310 | He divides the remainder, 640, into 2 parts of 320 | He divides one part of 320 among 4 seagoing men: 80 each | Finally, he pays 10% on the wages paid: 32

We can now imagine a very simple way of calculating, on a sheet of paper, what has happened. For instance, one can write down all the figures in two columns — one for the receipts, the other for the expenses — as follows:

	Receipts	Expenses
Purchase of fuel		150
Purchase of ice		20
Purchase of oil		50
Purchase of material		30
Purchase of food		60
Sale of fish	1000	
5 percent sales tax		50
Crew's wages		320
Wage tax		32
Total	1000	712

The skipper should be left with 1000 – 712 = 288. This is in fact what remains for all his expenses on the boat, plus 80 which is his share as a seagoing man. But he must not mix the two figures because the 80 have to be used for his family's livelihood and the 288 for expenses on the boat. This is what we shall always do — never mix the wage of the skipper, which is considered like all the other wages, with the boat account which is on the account of the enterprise.

Source: Laxenaire FAO 1973

or failed and how to use this experience in planning other similar schemes in the future.

SURVEYS

To survey something means literally to look it over, but here it implies far more than a casual glance; survey, as the term is used here means a detailed investigation, a long and careful look.

A survey of a particular fishery, if it is to be complete, would include an examination of the equipment and the way it is used. It would also include the times, seasons and places where it is used, the costs of each item used, the catch, its value and the methods used to process and market any fish that are caught. In a country where a number of different fishing methods are used, a full nation-wide survey would obviously take a great deal of time and cost a lot of money. The general principles involved in such a wide survey are the same as those involved in single surveys. It is in fact impossible to provide a complete analysis of most single fisheries without considering the other fisheries which may be competing for fish or competing in the same markets. Beach seines and gill nets may catch the same fish in African lakes; handliners and trap fishermen both catch groupers and snappers in many places. If one type of fish is landed in abundance fish prices will generally fall.

To return to the survey of a single method in one village or small area. The first thing we need to know is how many fishing units there are, the second is what a unit consists of and the third how profitable it is to own and operate such a unit or to be a member of the crew. While collecting information about this method, we must note how it affects or is affected by other methods.

Consider first, the boats. We need to know their size, how they are propelled, what crew they carry and what weight of fishing gear and fish they can take. We also need to know who builds them and how much this costs, who repairs them and how long they are expected to last. The cost of operating a boat includes the capital cost of buying a new boat, sails, or engine; the maintenance costs of replacement of worn out sails or of spare parts for engine repairs; cleaning and repairing the hull and the running costs where fuel is used. The capital costs are usually easy to get from boat builders or fishermen, the running and maintenance costs are more difficult to discover since the boat owners probably keep no records. If a loan has been obtained to buy the boat, engine or fishing gear, allowance should be made for repayment. If additional loans to replace expensive items are not likely to be available in the future, provision must be made during the working life of the present items to put sufficient money to one side to purchase replacements. This information can usually only be pieced together by questioning a number of people. It is important to plan in advance what questions to ask; to be sure you understand the answers; and to keep full records at the time. If you find that the answers differ widely from one unit to another, you may have to return and check that you have got the right answers in the first place. Costs may vary greatly over the years and generally speaking prices will have risen over the past few years, in most cases therefore, we can only quote prices at the time of the survey perhaps noting how these have changed in recent years. The suitability of the boat for the purpose for which it is used is a matter for the expert to decide, we can however note how far and fast the boats can travel; whether they are operated from open beaches or rivers; what their length, depth and beam are and how they are propelled. Also where and how the fishing gear and fish are stowed and what accommodation, if any, is available for the crew. Sketches or photographs will help to illustrate these facts.

The second consideration is the method of fishing. We should note the size of the nets or lines and the materials from which these are made. We should also note who makes them and what it costs to buy and maintain a set of gear. The most important points of all are when, where and how the gear is used. The way in which it is carried in the boat, prepared for use, and used must all be noted. Times and places in which the gear can be used may be restricted by its make-up. Shells or stones used

as sinkers may cause tangling and damage, and the use of crude wooden floats which require frequent drying are ways in which the materials with which the gear is manufactured may restrict its method of usage. Coarse or very weak fibres used in net construction may reduce catches. Crew positions during **shooting**, that is releasing the net or line into the water, or **hauling** which is recovering it, should be noted. It may seem that there are too many men in the crew; there may be social reasons for this, sometimes lack of capital restricts the number of nets or boats which can be owned in a village.

The way in which the fishing ground is found is important too. In some cases a net is shot more or less at random in a place where fish are expected to be found, in others a deliberate and careful search for fish is made. It may be necessary to search for a particular type of bottom on which a kind of fish is known to live. The fish sought may be known to live only in certain places such as reefs, holes, or trenches in the bottom. The way in which such places are found and the method used to return to them once their position is known must be noted. It may be necessary to seek the fish by looking for groups of fish swimming together (**schools**) in the water or on the surface, or by looking for feeding sea birds. At night, a search for some schooling fish may be made by looking for the glow they produce in the water, this is known as **'fishing the fire'**. Lures may be set to attract the fish to particular places or to hold schools of fish together. In some cases divers are used to look or listen for fish. Fish may also be attracted by throwing food into the water, this is called **ground baiting** for bottom fish and **chumming** for surface feeding fish.

Fishing times may be restricted to daylight hours, some fish will only take a bait during the day. In other cases fishing may be restricted to the dark hours, either because the fish would see the net and avoid it, or because the fish can only be found at night by 'fishing the fire'. Some fishing methods can be used only when currents are weak, so fishing may only take place near the times of neap tides, when the moon is in its first and last quarter. Some other methods work best when the currents are strong, that is during the spring tides at the times of the new and full moon or full and change of the moon. 'Fishing the fire' is possible only for about 20 days in any one month. On nights when the moon is full or nearly so, the light is far too bright for most of the night and it is not worth putting to sea for the short dark periods available.

The way the fish are removed from the net, the length of time they are left dead in the water in gill nets and the way they are treated on board will all effect the quality of the catch. Fish flesh starts to spoil as soon as the fish dies and the hotter it is the faster it spoils so that at tropical temperatures spoilage is rapid. Bruising the fish by throwing them about or walking on them also damages them. The worst possible way to treat fish is to leave it lying in the bottom of a boat in the blazing sun; the best is to keep it alive or ice it immediately it is caught.

Fishing may be possible only in certain seasons, either because the fish are **migrants**, (fish that move from one place to another to feed or spawn), or because the sea is too rough during a particular season or monsoon for the boats to put to sea. Some nets can only be used in calm weather, the 'purse seine' is an example. Sometimes the weather is too cloudy or hazy to enable the fishermen to find their fishing grounds, for very often these can be found only when the shore can be seen.

There will probably be religious or other social reasons why fishing does not take place on certain days during the year. Some days may be set aside for repairs of boats and fishing gear. Some people may own land which they have to work at certain seasons and crews may be short at these times.

An examination of these many factors will show how many days fishing is possible during the year. A note of the average catch on each trip makes possible a very rough estimate of the catch made during the year, in most fisheries this would be very rough indeed, since the catch will vary from day to day as well as from season to season. A reasonably accurate estimate can only be made if records of catches are kept regularly over a period of years. The same may be true of fish prices, estimating

the value of a year's catch can be difficult and misleading. Prices may fall very low when a lot of fish is caught and rise very high when little is available at the market, average prices can therefore be misleading. The way in which the catch is marketed is often an important factor, if there is no outlet for increased supplies there will be no point in trying to catch more fish. If heavy landings result in very low prices, this could mean simply that the fishermen must work harder or invest more capital for very little extra return.

Before any changes in the fishery are suggested, all these points must be carefully considered. The answer as to whether or not a change is likely to be profitable is found by considering the economic factors. These include the cost of operations and value of increased catches expected on making the alteration, but the social factors involved must not be neglected. If a large crew is carried because they are needed to paddle the boat the use of engines might put a number of men out of work; if net making is a well established village occupation the importation of ready made nets could have a similar effect.

Since it is important that accurate records are kept it is useful to design standard forms for completion by the surveyor. This reminds him of what questions to ask and enables him to record the answers quickly and easily (see Figures 1, 2 and 3).

So far we have assumed that if the fishing unit is made more efficient it would catch more fish. We have assumed that the fish are in fact there waiting to be caught. This may be true for migrant populations which move along the coast or come inshore for only part of the year, but it may be quite untrue for stocks of fish which live and breed only in the area fished. For all fish stocks there is a limit to the number which can be caught without endangering future supplies. For example, if all the adult fish were caught this year there would be no young ones next year; if too many adults are caught this year there may be too few young to catch next year. Where there is doubt about catch limits an investigation by a fisheries biologist, or team of fisheries biologists is needed, in many cases the answer cannot be provided quickly. We shall return to this vitally important point in Chapter 2. Carefully kept statistics showing the number of fish caught in an area over a period of years are very valuable to the biologist who is asked to say whether or not more fish should be caught. He also needs to know how the fishing effort has varied over the years, so this is another excellent reason for maintaining careful statistical records quite apart from the economic reasons already mentioned.

Much of the information needed in a survey should already be known to the field officers in the areas under survey. One of the most important functions of these officers is to learn all they can about the various fisheries in their districts. They cannot do this by sitting in an office, or on the beach, they must get out and about in their districts and go out on fishing trips with the fishermen. The efficient field assistant should know as much about each fishery as the fishermen themselves, and, in addition, have the technical knowledge and ability to discuss modern developments with them.

Economic, social, or biological factors may make some degree of control of the fisheries necessary. If, for instance, too many fishermen want to fish in one place it may be necessary to issue permits or licences or to restrict numbers. It may be necessary to allocate areas to different fishing gears or villages or tribes to prevent disputes, to make the use of some fishing methods illegal or to restrict the size of other fishing gears to permit small fish or some of the breeding fish to escape capture. For all these reasons and many others Government may pass laws for control of the fisheries and the task of administering these usually falls to the Fisheries Department.

FISHERIES LEGISLATION AND CONTROLS

Some of the fish resources available to any country are under the direct control of the Government of that country. These resources include those in its lakes and rivers

and within its territorial waters. Sea fisheries in international waters should ideally be controlled by international agreement, but any country can control the activities of its own nationals in international waters in various ways. Some laws are intended to protect the stocks of fish in particular areas, these are **conservation** measures. Other laws protect the rights of individuals, for instance, those which provide for the leasing of areas for shell fish culture and protect the owners of stocks of shell fish planted there, or those which provide for the leasing of fishing rights over lakes, dams, or rivers.

Other laws may regulate the type of boats which may be used in particular fisheries or lay down safety measures which must be observed by the owners, such as the carriage of fire fighting equipment, life saving equipment, or distress signals. Fishing boats may be inspected to ensure that they are seaworthy, that engines have been properly installed, or for various other features. They may be numbered, licensed, and registered. Such regulations are made for the protection of the fisherman. Licensing and registration may be taken as proof both of ownership and seaworthiness.

It may be necessary for fisheries legislation to prohibit the use of some fishing methods entirely. Poisoning and the use of explosives which are both wasteful and dangerous are forbidden almost everywhere. Sometimes the use of a particular fishing gear may be restricted, either to ensure that those using it catch enough to make a reasonable living, or to minimise interference with other gears. Measures such as these are intended to protect the fish stocks from over exploitation, thus ensuring that future supplies will be available and that the fisherman will continue to earn a living.

Sometimes the evidence obtained by scientists shows that fish of under a certain size should be allowed to escape capture in order to either permit a sufficient number to breed or to increase the weight of fish taken from the stock, in a year. This may be achieved by forbidding the use of nets with meshes under a certain size. It may be decided on scientific evidence, that fish should be left undisturbed during the breeding season. A close season, in which no fishing at all is permitted, may be introduced or certain areas may be set aside as reserves.

The enforcement of laws such as those suggested, and the licensing they may require is usually the duty of the field workers. They also have other tasks to perform such as statistics collection and assisting with extension and experimental work, all of which requires co-operation from the fishermen. Few people would suggest that this is an ideal arrangement, but where only a few officers can be employed, it may be unavoidable. It has its advantages too, if the fishermen recognise the licensing officer as a friend who helps with their problems they will make his licensing task easier; very often the licensing work and statistics collection can be undertaken at the same time. The licensing officer must understand the rules and laws he is required to enforce and be able to explain the reasons for them to the fishermen in a way they will understand.

Nothing creates more bad feeling than legislation which is unjust and few things give more trouble than legislation which cannot be enforced. In most cases both licensing officers and fishermen will be consulted before new laws are made. If there are obvious difficulties which might not be known to those making the laws they should be told of these. In some cases fees are charged for licences, the licensing officer then becomes a revenue collector and has to learn the correct procedure for accounting for Government money. The licensing officer may also have to prosecute offenders, but where possible this should be done by a senior officer or a member of the legal department. In either event the licensing officer would have to help with the preparation of the case.

Conservation laws, are, or should be, based on the advice of scientists. The scientific research worker will often be unfamiliar with an area in which he is asked to advise. The field worker, who should know the area thoroughly, may act as a guide and sometimes also as an interpreter. If he understands a little about fishery science he can

assist visiting scientific workers but even if he is not required to assist he should still understand what work is being done and why it is being done so that he can explain this to the fishermen whose co-operation may be needed.

In the past scientific research has not always been the direct responsibility of the Fisheries Departments. In some countries the result has been that work of little importance to the fishing industry has been done. It is best if the head of the Fisheries Department has control of all fisheries research. Technical research and experiment is one of the most important functions of almost all Fisheries Departments. Statistics collection and surveys may show what is needed to improve a particular fishery, they will not always show how the improvements might be carried out and for this experiments must be done.

EXPERIMENTAL WORK

The old ways are sometimes also the best ways, but there are often better ways, all the improvements in the ways in which fish are caught and preserved for marketing have been brought about by people who were curious and willing to try new methods. If a fisherman is making a living out of the equipment he already owns and has very little capital available, he will naturally be suspicious of any suggestion which involves change. He is interested only in making a profit so that he can feed himself and his family, not in catching fish. Before he tries something new he must be convinced either that it will make a profit or that it will show some other definite advantage and perhaps make his life easier.

The staff of a Fisheries Department, particularly the more senior officers, must know how things are done in other places; this may suggest how changes might be made locally. Unfortunately, methods which work in one place will not always work in another where the fish, the sea conditions or climate are different. No one would expect to be able to catch fish with a North Sea trawl on a coral reef, the net would obviously be torn to pieces. One might well expect, however, that a drift net similar to the one used in the North Sea for herring would catch herring-like fish in tropical waters and indeed it would do so. It may well be found that a net which is lighter and hung more loosely will catch more fish because some are too large for the mesh selected but can be tangled by a slack net. One can only find out by experiment.

In a similar way, if we know that there is a good method of salting and drying snapper in Malaysia we might expect it to work well in Africa. We cannot be sure until we have tried it because the fish are not exactly the same, the salt available in Africa might not be the same chemically as that in Malaysia and the climate might be slightly different. Even if the method did work well local people might not like the product, so we must not only prove that a method works, but also that the new product is acceptable.

Very few people ever make completely new inventions, most changes are gradual and brought about by making small alterations in existing methods and equipment. Many of these changes are the result of careful observation although some occur by chance. Some years ago when Canadian scientists were investigating the causes of 'pink' in salted fish they noticed that in one curing house 'pink' rarely occured. Pink is due to salt tolerant bacteria which make salt fish slimey and unpleasant to eat. These bacteria can live in salt; solar salt, produced by evaporating sea water, always contains large numbers. The curer whose product rarely suffered from pink always kept his salt in dry store for a long time, the bacteria died off and few were left to infect his salt fish. Later experiments have shown that storing salt for a period of years may overcome this particular trouble.

Critical observation may yield similar useful information. Why does one fisherman regularly catch more fish than the others? Perhaps he has a better, newer, larger fishing boat and newer fishing gear? He probably does, but he may own these only because he is more successful at catching fish. Perhaps he has the best crew? This may well be because he is known to be a successful fisherman and can therefore pick

and choose his crew because the fishermen know they will earn a good living if they work with him. Perhaps he just works harder, but, in some cases, his technique or his fishing gear will be slightly different from those used by his competitors. Similarly, there may be simple reasons why one curer's smoked fish keeps longer than anyone elses and has a more attractive appearance and flavour.

Experiments are, basically, of two types, in the first type, which might be called exploratory, we try to find out whether something will work at all. Is it possible to attract a particular fish species to a lamp or shade lure? Can we catch mackerel with a purse seine? Will iced fish stay in good condition long enough to be carried to a distant market? Such experiments may give a simple yes or no answer, sometimes they may suggest modifications which should be tried, such as brighter lights, a deeper purse seine, or better insulation in the fish boxes.

Most experiments are comparative, we must compare the results of the new method with those from an existing method. Comparing the catches of mono- and multifilament nets is an obvious example. If we want to know whether monofilament nets will catch more than multifilament we might decide to experiment in several different ways. We could, for instance, decide to do the fishing ourselves and if we have an experienced crew available this may be the best way, we can compare the catches directly ourselves and we should know not only whether the monofilament net catches more but whether it is easier or more difficult to handle. In fact, setting up a **trials unit** gives the best control over the experiment and permits quick modification of methods. However, the fact that the trials unit manages to make a method work successfully does not necessarily mean that it would work under actual fishing conditions. Sooner or later the local fishermen must try out the new equipment; providing a group of fishermen with the equipment to be tested may, therefore, provide a quicker answer than carrying out trials ourselves.

The essence of such experiments is to compare the new with the old. We might obtain this comparison by making a complete set of new gear and arranging for one fisherman to use it, and compare his catches with those of the other boats. If the answer obtained is to be reliable, we should know whether his catches are usually greater or less than those of the other fishermen. We could make up a complete set of gear and use it for trials ourselves, if we do this we must first obtain a set of traditional gear and fish this against the local fishermen and see how our results compare with theirs.

We could of course, make half our fleet of nets with multifilament and half with monofilament. This would give us a direct comparison between the two, if we do this we must eliminate, as far as possible, other likely causes of differences in the catches. The nets nearest the boat may catch less fish than those further away because the boat frightens the fish; the nets closer inshore may catch more or less fish than those in deeper water, so we should change the positions of the different sorts of nets at intervals and plan in advance how to do this. If we have a large number of nets (a long **fleet** of nets) the nets which are shot first may fish much longer than those shot last, and this would be another good reason for changing the shooting order.

The way in which the experiments are planned is therefore of great importance. Field officers will not often be left to plan trials by themselves, but they must understand how this is done and why it is important that the plan be followed accurately to get maximum information. Conditions will inevitably vary from day to day and it is often impossible to repeat the experiment under exactly similar conditions. It is, therefore, most important that full and accurate records are kept of every trial. Recording must also be planned in advance. In the case of our simple experiment with mono- versus multifilament drift nets, we might decide to record the weights of fish caught by each type of net every time they are fished. If the fisherman is carrying out the experiments for us this may well be all the information we can hope to get. We could expect to get a lot more information than this from a set of experiments and should certainly try to do so. We are not only interested in whether monofilament nets catch more fish than multifilament nets, but which is likely to be more profitable to use, this is certainly all that really interests the

fishermen. We should, therefore, record how much time and money is spent on the repair of each type of net and how long each lasts in use. One type of net may damage fish more than the other and we should note this and record whether it affects the value of the catch. One net may catch more of one species of fish, or larger fish, than the other. We may therefore need to analyse the catches of each.

In order to be sure that all the information needed is recorded every time, we should design and use record forms. Some of the things in which we may be interested will be matters of opinion, for example water colour, wind strength and so on. If different people are going to keep records, there must be prior agreement about the way in which such things are to be recorded. In some experiments we may need to use instruments such as thermometers, wind gauges, hydrometers and others. We should check and see that these give the same readings under identical conditions and that everyone taking readings reads the instruments in the same way.

Once a series of trials has been completed the results should be written out so that everyone has access to the information gained. This should be done even if there are no conclusions drawn or if the experiment has apparently been a complete failure. By doing this it may prevent someone else trying the same thing and spending more time, energy and money to obtain the same result. It will certainly help other people avoid any mistakes which have been made and may serve to show that other to experiments are needed and how they should be carried out.

If we manage to prove that something works, the next task is to convey this information to the people who can use it. In doing this we are extending or putting out knowledge. Sometimes a special branch of the Department is engaged on extension work, more usually every field officer is part of the extension service.

EXTENSION SERVICES

An extension worker's task is to convey information. He may do this in a number of different ways, for the field worker it usually involves talking to small groups of fishermen in an informal way while they are mending their nets or having a break in a coffee shop. When more important information needs to be given, a more formal meeting may be arranged. In either case the time and place should be carefully chosen, obviously one does not try to talk to a group of fisherman who are just preparing to go to sea or have just returned and who are busy with the selling of their fish. Far better to talk to a group who are relaxed and have time to think, absorb information, ask questions and make suggestions.

If the fishermen can read and write an advisory pamphlet can be prepared. This is a useful technique, for drawings, sketches and photographs may be included which help to make understanding easier. In some cases even where the fishermen are illiterate, pamphlets which consist almost entirely of diagrams may help to get a point over. Radio talks either as a regular feature or on those occasions when there is something of note to report are also useful. These reach a wide audience and stimulate discussion. If the new technique is very different from the old one, it may be worthwhile filming it and using the film for training.

The best way to teach people about a new technique is obviously to demonstrate it to them, to show them how it works and that it does in fact work. A boat full of fish or a pile of well cured fish is a very much more impressive demonstration than a table of statistics or vague talk about prices. Demonstrations may be organised by converting a trial unit to demonstration work, perhaps by providing a lorry to move the crew and equipment from place to place, or by teaching a few fishermen to do demonstrations, relying on them to show others. In some cases the field staff of the Department can demonstrate new techniques using equipment already available. It may be possible for instance to demonstrate better salting and drying methods in a village. This can be done by using existing salting tanks, cleaning and washing the fish properly and then drying it in the shade instead of the open sun.

Where new equipment is involved this may be loaned or hired to fishermen so that they can try it out for themselves. Before equipment is loaned or hired, the men who are going to use it may need some training to ensure that the equipment is not damaged and to see that it is used correctly. This might not be necessary, for instance where new types of nets are involved. It would certainly be necessary where engines are being introduced for the first time. A field officer might then accompany the boat and act as engineer until a member of the crew learns to operate the engine properly.

Even when a new method has been adopted and new equipment purchased by the fishermen, the field officer must continue to visit and advise them. He must, for instance ensure that the engines are properly serviced and that the fishermen understand how to care for synthetic nets. This continued supervision is particularly important in pond fish culture, if people have been persuaded to make fish ponds and stock them, field staff must visit regularly to advise on how the fish should be fed, ponds kept clear and predators and disease controlled. Regular visits will help to keep the owners interested and may avoid costly mistakes.

The follow up is always important, but it is particularly important with the first few new units. All the other fishermen or prospective pond owners will be watching with interest to see how the new projects work out. If the first units fail to produce the expected results it would be very difficult indeed to get further similar projects started. This means that care must be taken in selecting the people to try the new methods. One must also be careful not to start too many new projects at one time, where possible the number of new units should be restricted to a number which can be supervised easily. This is not always possible for one cannot prevent people buying new equipment if they have the money available. It is important not to make over-enthusiastic claims for a new method, this is an obvious point, but it has sometimes happened that in their desire to get things started field staff have made exaggerated claims for a new technique. When the results have not proved to be as good as the fishermen were led to believe, they feel that they have been ill-advised, and quite rightly so too.

Many examples could be cited of places where fish farming has given good results in experimental ponds carefully tended by Departmental staff, while similar ponds in inexperienced hands have produced little or no fish. Many peasant farmers in the tropics do not feed their livestock; chickens and goats run almost wild and find their own food. No one feeds the fish in lakes and rivers so it is perhaps easy to understand why the peasant farmer does not understand at first that he must provide food for his fish. The answer is, of course, that while six chickens may find their own food by scratching around his house, six hundred could not do so; if there are a few fish in a big lake they can forage for themselves too, but if the small ponds hold a large number of fish, food must be provided or the fish will starve and perhaps die, they will certainly not grow. This sort of difficulty can be overcome by demonstrating not only the right way but also the wrong way to do things. If the farmer is shown two ponds side by side, one full of fat fish that have been fed properly and the other with a few small fish in it that have not been fed, and the different treatment the ponds have received are explained to him, this will be a much more impressive demonstration than one pond full of healthy fish. One cannot always arrange demonstrations of this kind, one would not normally wish to run one engine with oil and one without, in order to show that the unlubricated engine seizes up. There are always ways round this sort of problem, for example showing the worn and melted bearing from a seized engine, not such an impressive demonstration, but cheaper and reasonably effective.

So far we have assumed that you know the answers to any questions you might be asked, but sooner or later someone asks a question you cannot answer immediately. No one can be prepared with all the answers to all of the questions so there is no shame in admitting that you do not know. In fact this is what you should do, at the same time promising to try to find an answer. Another member of the Department may be able to provide an answer, or you may be able to find the answer in a book. At the end of each chapter in this book there are lists of books which provide some

of the answers. You must, however, be very careful about answering questions from books; most of the books available have been written about conditions in temperate climates. Similarly a fishing method which works in cold muddy seas, may not work in a clear lake or a process which is effective at 5°C may not be effective at 30°C. Sometimes a question cannot be answered without first performing some experiments. However the experience recorded elsewhere in books will be a useful guide to the way to experiment and also to the sort of results you may expect. This is, or should be, a two-way trade, other people write up their experimental results so that you have the benefit of their experience and your Department should do this too.

TRAINING WORKERS IN THE FISHING INDUSTRIES

Although new methods are best demonstrated in the field some things cannot easily be taught in this way. Demonstration of a new fishing method is best made under conditions in which the fisherman might use it, but some of the basic skills needed by some, or all fishermen, are better taught in formal classes where theory and practice can be taught at the same time. Net making and repairing, navigation, engine maintenance and repair are obvious examples. These subjects are taught most easily if a quantity of equipment is available on which the students can be trained. Engine repair and maintenance can only be learned by taking engines to pieces and putting them back together, for this one needs discarded engines so that it does not matter too much if the students damage them. Engines in running order on which faults can be diagnosed and corrected are also needed, as are work benches, tools, and a range of spare parts. A collection such as this cannot easily be carried from place to place, so a school is needed.

A formal school offers other advantages, the greatest being that the students can be available full time for instruction. Trying to teach people who are carrying on their normal fishing activities at the same time is difficult, training must be fitted in with the normal daily routine and some people may attend regularly while others will not. A lot of the instructor's time could be wasted in these circumstances. A formal school can set examinations and thus check on the progress of its students. There is, or course, the disadvantage that the students will be away from home, this usually means that living accommodation and food must be provided, and that an allowance must be paid to enable the trainees to support their dependents.

Boat building is another subject best taught formally in schools, this requires a rather long course of training, but if the school is well planned some of the costs may be offset by selling the boats that are built.

Where a fisheries school exists new recruits to the departments may be required to attend a course there, later in their service some of them may serve as instructors. Running even the smallest school is an expensive undertaking and it is necessary to select the students carefully. Since the field officers of the Fisheries Departments are the officials most closely in touch with the fishermen and other possible trainees, they must often help to select the students. Usually the minimum qualifications for entry will be laid down, very young or very old students would be unlikely to benefit from a course so an age range may be stipulated. Often a certain number of years experience of fishing or of a trade connected with the fisheries will also be required. Some schools can only accept students who can read and write, in other cases instructions can be given in only one language. Obviously only students who meet all the qualifications laid down for entry should be selected, selection amongst those qualified is difficult unless you know all the candidates equally well. Preference should be given to either the candidates who seem most likely to benefit from training or those whose community may benefit most from having a trained member.

In addition to the specialised work outlined here, Fisheries Departments must carry out routine administrative duties common to most Government Departments.

Annual or monthly reports must be produced, Government revenue and expenditure must be accounted for and members of the Department may be asked to advise Government as to how various measures would affect the fishing industry.

Other people may ask for advice or information too, would-be foreign investors may want information about the country's fisheries and international organisations may ask for statistical information. In many cases the Department must represent the interests of the fishermen and fishing communities and inform Government of the need for harbour facilities, roads, markets etc., on which public money should be spent. The Department may help to administer loan schemes, advising on the purpose for which loans should be made available, and who should receive the loans. Most of the field officer's work involves the fishermen, fish sellers and other people connected with the industry. His relationship with these people is of the utmost importance, their confidence must be gained and never abused, they must be free to visit him and to consult him at any reasonable time and know that they will get the best advice and assistance available.

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Chapter 2

Fisheries science

The sciences are branches of knowledge in which general laws are made in an attempt to explain and understand natural events. A scientist therefore asks questions, tries to find the answers and to explain them. Biology is the study of living things; zoology is the study of animals, and botany the study of plants. These are the natural sciences whereas chemistry and physics are the physical sciences and involve the study of non-living things. Today so much is known in any one science that scientists tend to specialise in one smaller subject. Thus a man who studies insects is called an entomologist, one who studies bacteria a bacteriologist and one who studies fungi a mycologist. An ichthyologist studies fish but is usually less concerned with the practical application of the knowledge he obtains than with obtaining new knowledge. The fisheries biologist, whose aim is to obtain knowledge of practical use in the fishery, needs to know some chemistry, physics and geology as well as biology. He must know something of statistics and fishing methods and must often be a practical navigator and seaman as well. To this extent he is, perhaps, less of a specialist than some other scientific workers but fisheries biologists also specialise, for while one man studies the fish themselves, often spending most of his life working on one species or group of species, others study the plankton (the animals and plants which drift in the surface and middle waters) or the bottom living animals (the benthos or benthitic animals) and so on. The man who studies plankton is studying some of the food fishes may eat and other animals which compete with the fish for food, so is the man who studies the benthos.

THE NEED FOR MANAGEMENT

It is obvious that if one fished a small pond efficiently and caught all the fish in it there would be none for tomorrow. If you want fish from the pond not only tomorrow but next year too, you must leave some fish to breed. If you want to take the greatest possible weight of fish from the pond each year you need to know a great deal about the way the fish live in the pond. For instance you must know how many fish are present, what they eat and how much food is available, how fast they grow, how large they must be before they can breed, how many young they will produce, what food and other conditions the young fish need and how many of them are likely to live until they are big enough to be caught. You also need to know how many are likely to die from natural causes such as disease, **predation** (being eaten by other predatory animals) or old age. Given all this information it would be possible to decide to catch fish only when they reach a certain size and to leave enough fish in the pond to maintain the stock by breeding. If more than one species is present in the pond the information is needed for each one and since climatic and other conditions vary from year to year the answer can only be an answer for average expected conditions. Some of the variables can be followed or **monitored** almost continuously, for instance records of catches can be kept and regular fishing of the small fish undertaken so that growth and numbers can be checked.

It is perhaps less obvious that it is possible to catch too many fish from a large lake or the open sea but records of many commercial fisheries show that this can in fact

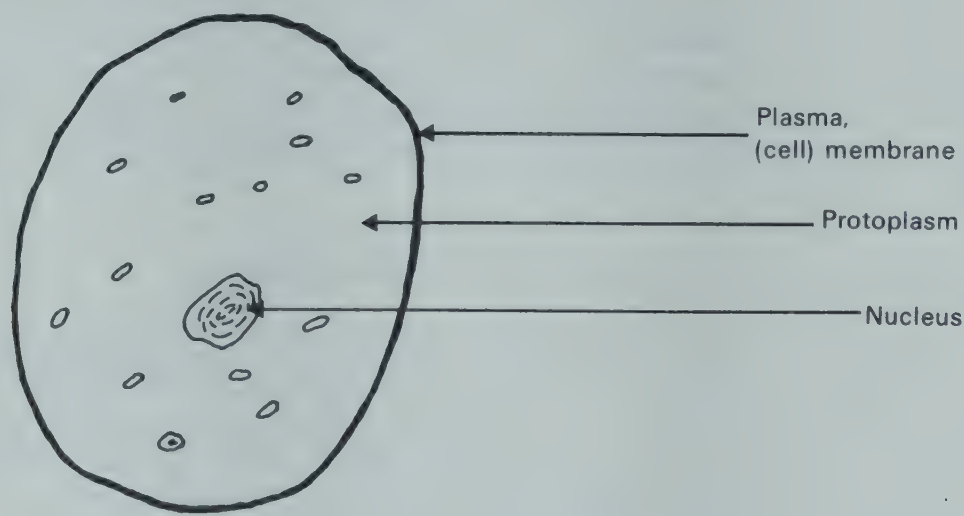
happen. When this does happen a day's fishing produces much less fish than formerly and the total catch in a year is less. Therefore it is just as important to apply management techniques to commercial fisheries as to the small pond. In fact it is much more important, for the livelihood and food of many people would be lost if a major fishery was overfished and damaged beyond repair. This is why Governments employ biologists and other scientists to manage the fisheries. While their objective is usually to find out how much can be taken from the stocks of fish, many scientists are now working towards more advanced techniques which would make it possible to increase the stocks and thus increase the catch or **yield** by applying principles similar to those used in farming the land. We will return to the work of the fisheries scientists in more detail later but we will first consider what fish are and how they live.

PLANTS AND ANIMALS

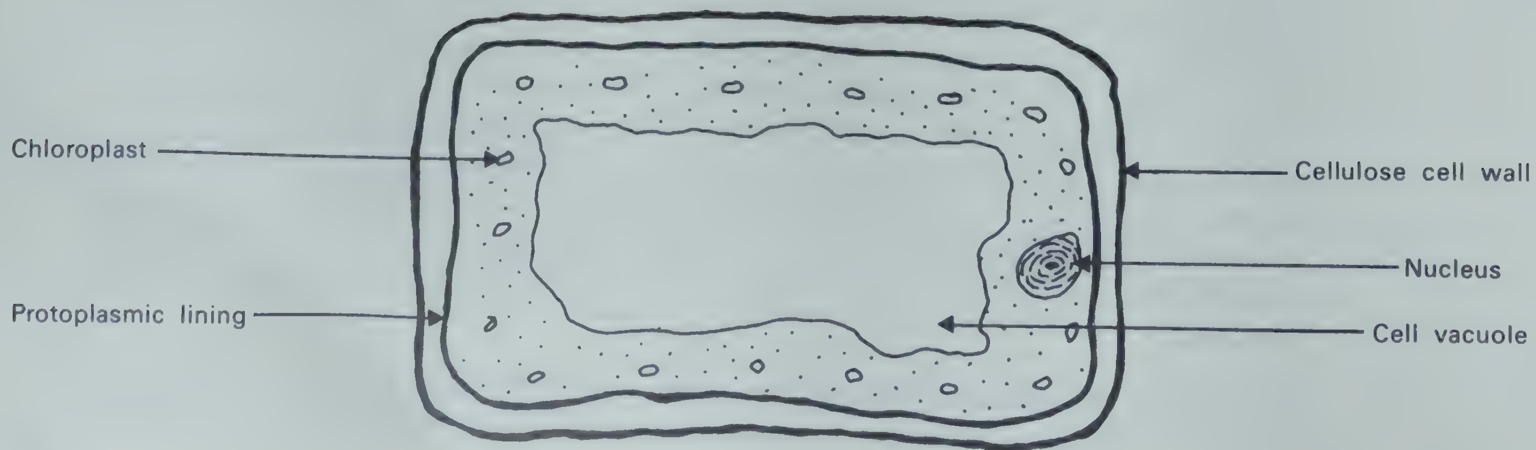
All plants and animals are made up of small units called cells, the simplest living things consist of only one cell which performs all functions such as digestion, excretion and reproduction which are undertaken by specialised cells in more advanced animals and plants. The cell is bounded by a wall, this may be thick in some plant cells but is very thin in almost all animals cells. It contains a mass of living jelly called **protoplasm**, and includes the **nucleus,** a more or less spherical body, which controls the activities of the cell. Figure 6 outlines the general differences between plant and animal cells. No cells look exactly like these drawings as most

Figure 6
Cells

A generalised animal cell



A generalised plant cell



are very specialised and carry out a limited number of functions. Thus muscle cells are long and fibre-like and are able to contract and expand rapidly in length. Some cells excrete special chemical substances; the cells forming the nerves act as message transmitters and so on.

Groups of specialised cells are referred to as tissues, these form the functional parts of the body, the organs such as the heart, stomach and liver. The organs which have particular duties are described as forming part of a **system**, for example, the digestive system, which includes the stomach, liver, pancreas, gall bladder and intestine. The biologist may use the term gut to include stomach and intestine, the fisherman describes all the contents of the body cavity as guts and their removal as gutting.

Discussion of the functions performed by the various parts of the body must include some reference to chemistry, the study of the composition of living and non-living substances. Matter is composed of **elements** of which more than one hundred are known. An element is a substance which cannot be split into anything simpler by chemical methods. Elements can be changed only by using enormous amounts of energy, as when the methods of atomic physics are used. Some elements are solids like carbon and copper, some are liquids, such as mercury and bromine, some are gases, such as hydrogen, oxygen and nitrogen. The chemist divides these into metals and non-metals.

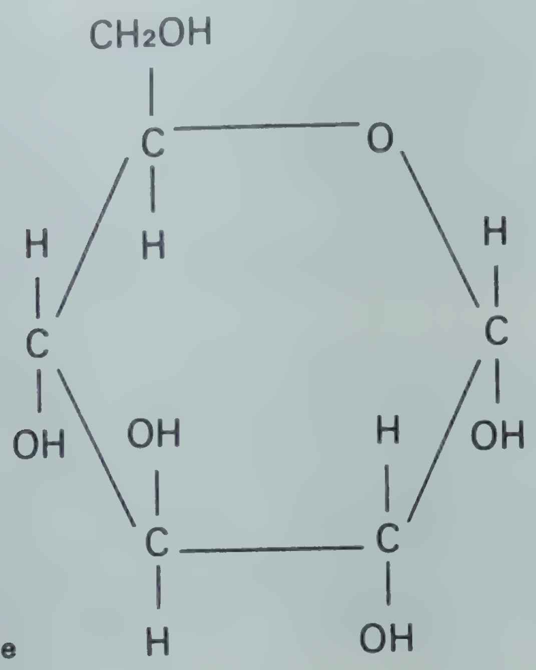
The smallest particle of an element which can take part in a chemical reaction with another element is called an **atom**, this is the smallest particle which can exist without losing its chemical identity. Most elements do not exist singly, or free, in nature, usually two or more are found in combination as **compounds.** Compounds are substances containing two or more elements combined so that their properties are changed. Thus oxygen and hydrogen can be mixed together to form a gaseous mixture but, if combined in proportions of two atoms of hydrogen to one of oxygen they form a new substance, a compound called water. The smallest part of a substance, whether an element or a compound, which can exist in a free state is called a **molecule.** When atoms combine to form a molecule of a particular pure substance they always combine in the same fixed proportions. The number of atoms of hydrogen which will combine with or be displaced by one atom of an element is called the **valency** of that element. Oxygen has a valency of 2, nitrogen 3, carbon 4. Thus water always consists of two atoms of hydrogen combined with one of oxygen, carbon dioxide of two atoms of oxygen combined with one of carbon.

It would be cumbersome to always write out these reactions in full and the elements have been given symbols so that a form of shorthand can be used. Sometimes single capital letters are used, sometimes one capital and one small letter thus carbon is C, oxygen O, hydrogen H, nitrogen N, sulphur S, iron Fe, lead Pb, sodium Na and chlorine Cl. Many of the symbols are shortened forms of the latin name for the element, thus iron (Ferrum) is Fe. These symbols are combined into molecular formulae (singular, formula) which can be used to describe single substances or describe how they react together. Thus H_2O represents water. HCl, hydrochloric acid consists of hydrogen and chlorine atoms combined in equal proportions (since both gases have a valency of one). Simple formulae are less useful when more complicated substances are under consideration, thus the simple sugars glucose and fructose both have the formula $C_6H_{12}O_6$ yet they are different substances. This is due to the different arrangement of the atoms in the molecule. Such arrangements are represented by **structural** or **spacial** formulae. (See Fig. 7).

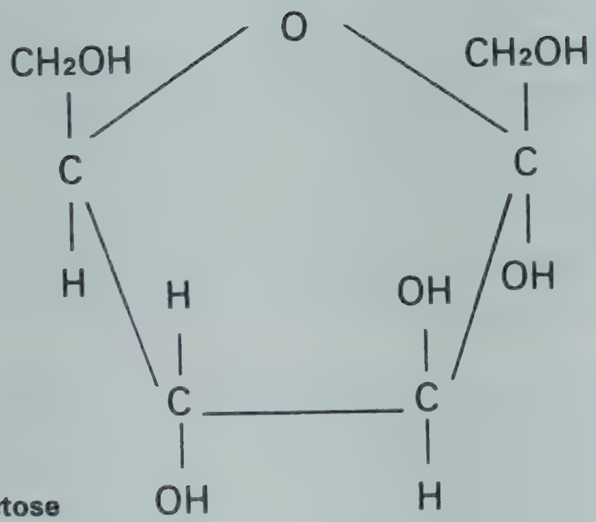
Inorganic chemistry is the branch of science concerned with the study of substances which do not contain carbon – hydrogen bonds (linkages). Important groups of compounds are the acids, salts, bases and alkalis.

An acid is a compound containing hydrogen some or all of which can be reduced by a metal to form a compound known as a salt. Acids turn the indicator litmus, red, in dilute solution. All acids have a sour (acid) taste, most will react with a carbonate (such as washing soda or calcium carbonate) to produce carbon dioxide, which is given off as a gas. Concentrated acids may cause severe burns.

Figure 7
Structural formulae of glucose and fructose



Glucose



Fructose

Bases are substances which will react with an acid to give a salt and water only. Other compounds consist of combinations of metal and oxygen and are known as oxides and peroxides. Thus the base, copper oxide, reacts with sulphuric acid to give copper sulphate and water, sodium peroxide reacts with hydrochloric acid to give sodium chloride and water. Bases which are soluble in water are called alkalis, these turn litmus blue and have a slippery or soapy feel when handled in solution, some are very dangerous to handle for they are **caustic** and may cause severe burns.

A salt is a substance in which the replaceable hydrogen of an acid has been wholly or partly replaced by a metal.

Organic chemistry is concerned with the compounds which contain **carbon–hydrogen** bonds. These include substances of which living matter is made and the term organic

comes from organ, it being thought at one time that carbon compounds could be formed only by living matter. Structural formulae illustrate the way in which atoms are combined. Substances formed from carbon and hydrogen only are called hydrocarbons.

Hydrocarbons can be burnt as fuels but are not useful as food (although both burning and respiration involve combination with oxygen). The substances which can be used as foods include carbohydrates (compounds which contain carbon, hydrogen and oxygen) and proteins. Proteins differ from carbohydrates in that they contain nitrogen in addition to carbon, hydrogen, and oxygen. In the carbohydrates (sugars, starches, cellulose) hydrogen and oxygen are always in the proportions in which they occur in water, that is 2:1 and carbohydrates can be represented by the general formula $C_x(H_2O)_y$. Thus sucrose, the sugar we buy in shops, also known as cane sugar, is $C_{12}H_{22}O_{11}$. When combined with water in the presence of a dilute acid and warmed this breaks down to give one molecule of glucose and one molecule of fructose thus

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{acid}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

a reaction of this type is called hydrolysis, which means splitting with water (see Fig. 7 for formulae).

Hydrolysis would be too slow to be of much use in **digestion.** This is the process by which living things break down complex substances such as starches and sugars to simpler substances which can be absorbed by the cells, where they can be used as a source of energy. In living things the break-down is accomplished by **enzymes,** organic substances (proteins) which accelerate these reactions without themselves taking part or being changed. Starches are more complex carbohydrates than sugars and as some are not soluble in water they can therefore be easily stored. These can be digested by animals and plants. Cellulose is a more complex substance which cannot be digested by animals such as fish. Snails and some simple animals can make use of it however, and the gut of animals such as cows contain bacteria and simple animals which digest cellulose so that the cow can make use of it as food. The structural parts of plants, stems, leaves, and so on, consist largely of cellulose.

Oils differ from carbohydrates in that the oxygen and hydrogen are not combined in the same proportions as in water, oils consist of compounds of glycerol and fatty acids, fish oils are largely of the type known as unsaturated fatty acids. Such unsaturated acids combine readily with oxygen forming substances called peroxides. Oxidised oils are called rancid oils and these are indigestible and may be poisonous to an animal which consumes them. Oils and fats can be used as energy sources by living things, they contain large quantities of carbon and provide roughly two and a half times more energy per kilogram than carbohydrates. Fat is thus a particularly useful way of storing potential energy and fish and most other animals store fat rather than carbohydrates, although relatively small quantities of glycogen or animal starch are stored in the liver for use as a rapidly available source of energy.

Proteins consist of substances called amino acids (nitrogen containing acids) in various combinations. Some of these can be converted into other amino acids in the body so that a shortage of a particular amino acid in the diet may not be too important. Others cannot be made in the body in this way, and these are known as **essential amino acids.** When an animal eats a particular protein it is digested and broken down into the amino acids of which it is made. Since proteins consist of different combinations of amino acids some are more useful than others as food to an animal which needs to build up its own body proteins. Some foods have only small quantities of the essential amino acids in their proteins but with a mixed diet these deficiencies can usually be balanced by other foods. For example most plant proteins contain only small quantities of the essential amino acid lysine. Lysine is, however, present in meat and fish so animals need to include animal protein in their diet or to eat vast quantities of plant material to supply the lysine. If the food

supply has insufficient carbohydrates and oils to supply the energy needed, proteins can also be used for energy. A starved animal uses its fat reserves first as food and then uses some of its proteins for this purpose. If starvation is prolonged the animal dies.

Living things have a number of features in common which distinguish them from the non-living. All are capable of **growth** at least in the early stages of life, all can maintain the body by replacing worn out tissue and all can **reproduce** their own kind, all are **sensitive,** that is they can detect changes taking place around them and react to these. All have certain vital activities in common, these are **locomotion** (movement), **nutrition** (the ability to digest food substances by breaking these down to simpler substances which are assimilated or taken into the body's cells). **Respiration,** the process in which energy is liberated from materials within the body is essential to all living things, and all must rid themselves of the waste products of this and other activities, a process called **excretion.**

There are, however, certain fundamental differences between animals and plants. The most obvious is that animals are generally more mobile than plants, the herbs with which we are all familiar are rooted down while such animals as fish, frogs, and snakes are not. However, many microscopic plants move freely in water, while some animals such as coral and shellfish do not. The young stages or **larvae** of such animals swim freely. There is a less obvious but much more important difference between animals and plants in that only plants can manufacture food substances from simple inorganic salts, water, and carbon dioxide. Plants can do this only in light and the process is therefore called **photosynthesis** or manufacture in light. During photosynthesis plants use pigments (coloured compounds), one of which is chlorophyll, to convert the sun's light energy into chemical energy for manufacture of carbohydrates. Not all living things classified as plants can carry out this process, fungi and other plants which do not possess the chlorophyll pigments are dependent upon chlorophyll possessing plants for the manufacture of their food as are all animals.

The fundamental process of photosynthesis involves plants combining water and carbon dioxide to manufacture a simple sugar, in the chemist's shorthand this would be written:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

From which we see that six molecules of carbon dioxide are combined with six of water to produce one molecule of simple sugar and that six molecules of oxygen are released. In fact the process is far more complicated than the shorthand suggests as there are intermediate products in the reaction. Simple sugars are not very suitable for storage and more complex sugars, starches, proteins and fats are produced for this purpose. Substances insoluble in water are advantageous in some ways. In the dark a plant must continue to respire for it still needs energy, and in the plant as in the animal a simple sugar is oxidised to release the energy locked up by photosynthesis together with carbon dioxide and water.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 + \text{ENERGY}$$

This process also takes place in several stages each of which is accompanied by the release of energy. The release of oxygen during photosynthesis is very important for fish because much of the oxygen dissolved in water comes from this source, the rest being obtained from the air. The water in fast moving rivers which tumble over rocks is well oxygenated, as is that in wave tossed lakes, for new water surfaces are constantly presented to the air. In stagnant swamps, especially those filled with rotting vegetation which also uses oxygen, the water has very little oxygen dissolved in it.

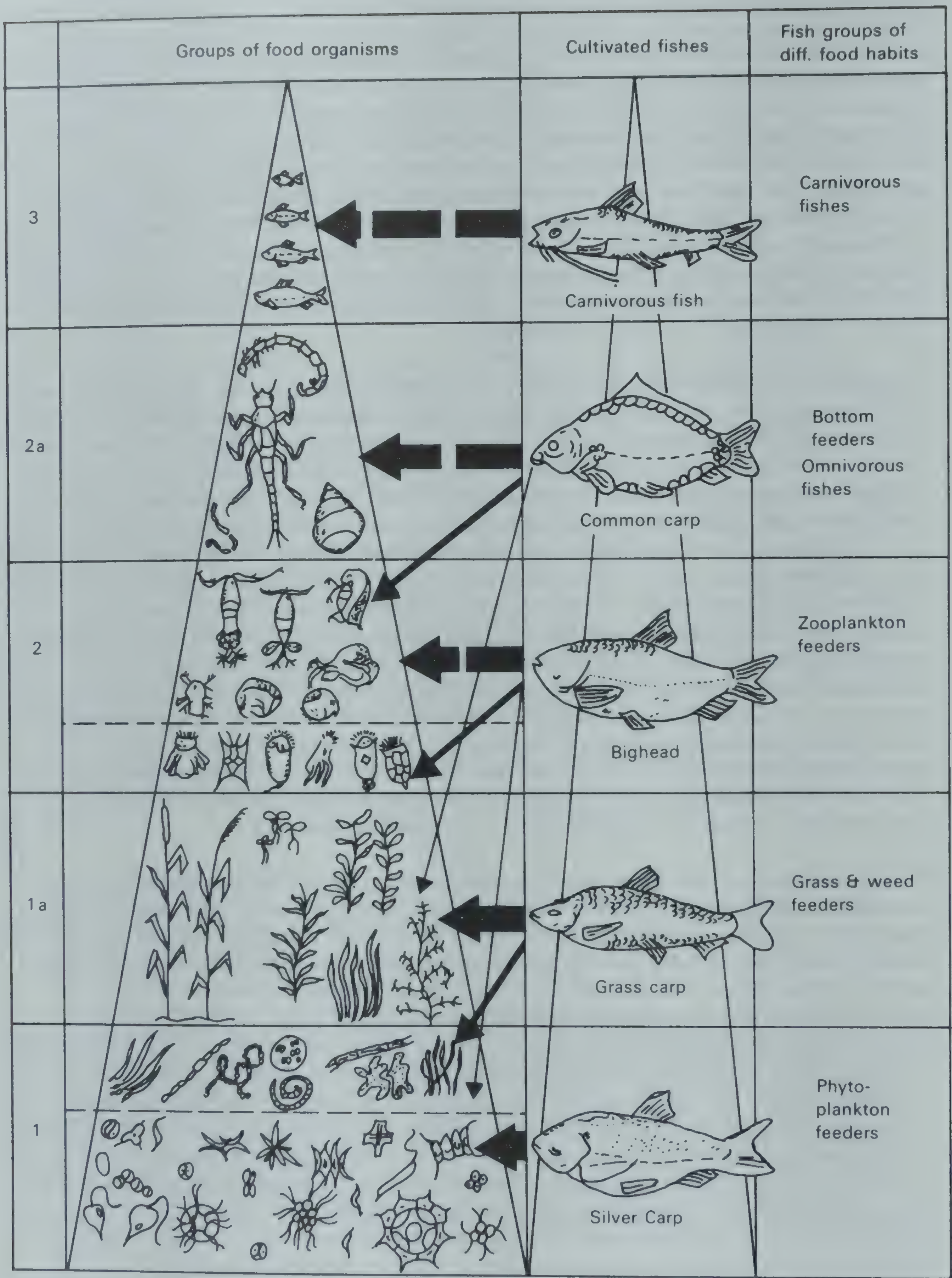
Since **aquatic** (water inhabiting) animals, including fish, are dependent on aquatic plants for the food they eat, it is obvious that the amount of fish produced in any body of water depends on the richness of the plant crop produced by the water. Aquatic plants must obtain carbon dioxide from the water for the manufacture of organic substances such as sugars, they must also obtain certain minerals which are needed for the manufacture of the plant body. These substances include nitrogen, phosphorus, silica, sulphur, magnesium, iron, copper, zinc, calcium and chlorine. These must be in solution in the water and they are present as salts; sulphur may be present as sulphate, phosphorus as phosphate, silica as silicate and so on. A shortage of one or more of the essential elements may restrict the growth of **phytoplankton** (drifting minute plants), thus in some English lakes the early bloom of phytoplankton uses all the available silica and this bloom of plants, called diatoms, is followed by blooms of other plants which do not need silica. The level of phosphates in the East African Lake Victoria has been shown to be very low, presumably this limits the phytoplankton growth. Adding phosphates to fish ponds can often result in rapid plant and thus fish growth.

Light does not penetrate to the bottom of a deep sea or deep lake. Since plants can only manufacture food and grow in light, only the upper waters produce plants and thus food for fish and other animals. The plants which are attached to the sea bed or bottom of lakes or rivers are relatively unimportant as fish food producers. Of far greater importance are the tiny plants, often single celled, known as **algae**, many too small to be seen individually with the naked eye, which form the plant plankton (or phytoplankton). Although these plants are individually small their total bulk is often enormous and in some cases they give a red, green or brown tint to the water in which they live. Such tiny plants are eaten whole by some species of fish, some die and decay, while others are eaten by the tiny animals which form part of the animal or **zooplankton** or by other animals such as worms and shell fish. The smaller **zooplanktonic** animals are eaten by larger ones and by other animals such as fish; some fish eat the larger animals or other small fish. Animals which eat plants are called **herbivores** or **herbivorous** animals, those which eat animals are **carnivores** or **carnivorous** animals, other terms have been coined which indicate the food eaten, for example the **molluscivore** or mollusc (shell-fish) eater. Animals which hunt and capture other animals are called **predators** or **predatory animals.**

When a plant or animal dies its body is broken down by agents such as bacteria and the salts required by the plants are again released into the water. The same thing happens to the waste products of animals. There is thus a cycle of production in water. Dissolved salts are used by plants to make the plant body and in turn to make animal bodies, before being finally returned to the water. The sequence in which phytoplankton provides food for zooplankton which is eaten by other animals is often referred to as a food chain. It is in reality more like a pyramid than a chain for a kilogram of phytoplankton does not make a kilogram of zooplankton, some of the substances in the plant are of no use to the animals and these are thrown away, or excreted. Some of the energy containing substances, the foods, must be used for the maintenance of the body's activities and only when this maintenance requirement has been met can any surplus be used for growth. This applies also when one animal eats another but since the two animals bodies would be chemically similar to one another the losses would be less and the conversion ratio better. It is difficult to obtain accurate figures for the conversion of food by aquatic animals and estimates differ rather widely. A conversion ratio of seven or eight to one would be considered good, this is the sort of ratio expected when a predatory fish eats another species of fish. The first fish however could be the product of a food chain in which perhaps 140 kilograms of plant material was converted to 10 kilograms of zooplankton which was then converted to one kilogram of fish. One kilogram of predatory fish thus represents $7 \times 10 \times 14 = 980$ kilograms of plant material. This pyramid is illustrated in Figure 8.

It will be seen that fish that can eat plants are making very much better use of the food produced in a body of water in terms of fish flesh production than are predatory fish. This is why predatory fish are seldom used in farm ponds, and then only in small numbers to eat unwanted small fish. Figure 9 shows the production cycle in a

Figure 8
Food and fish pyramids



Notes:

Vertical column 1: 1, 1a Primary producers; 2, 2a Secondary producers; 3 Tertiary producers.

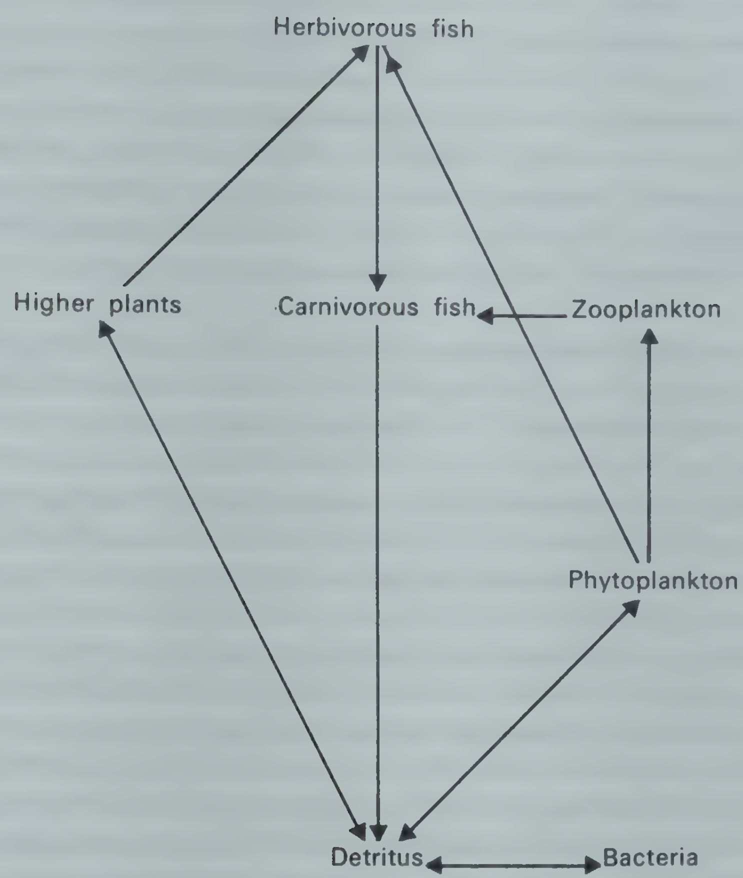
Vertical column 2: The pyramid of groups of food organisms.
1 Planktonic algae (micro-phytoplankton and filamentous algae);
1a Emerging and submerged plants;
2 Zooplankton;
2a Bottom fauna;
3 Weed fishes.

Vertical column 3: The pyramid of fish groups with different food habits. The main arrows indicate the relative sizes of the food chain of the fish in question

Vertical column 4: General fish food habits.

Source: Woynarovich FAO 1975

Figure 9
A food chain



body of water in a much simplified form. The actual weight of fish flesh produced in a given time depends on the amount of food made by the plants and the way in which this is used by the fish and other animals present, as fish of different species may have to compete with one another and with other animals for food. If the food is sufficient only for body maintenance there is no increase in the weight of fish flesh.

As we have seen, the amount of food made by the plants depends on the supply of nutrient salts available to them and the amount of light reaching the water in which they live. Temperature is important too, for plant growth is slower at low temperatures than at tropical ones, in water close to freezing little growth takes place, in the tropics growth continues throughout the year. Light penetration depends on the angle at which the light strikes the water and on the turbidity of the water, small particles, including plankton, cause scattering, so that penetration is not so deep as in clear water. Light penetration is obviously of importance in deep waters where photosynthesis cannot occur except in the surface layers. However the presence or absence of the necessary salts is often of much greater importance. Productivity is in fact often limited by the availability of a particular element in a form suitable for uptake and use by the plants. Under favourable conditions the minute plants of the plankton grow until each reaches a certain size and then each divides into two plants. In some circumstances sexual reproduction takes place in which two individuals unite and then produce a much larger number of young plants. Each new individual grows in size until it too reproduces. Rapid growth and reproduction of this kind produces what is called a **bloom** of algae which may colour the water. The bloom cannot continue indefinitely for sooner or later the plants will have used up all of a particular element in the surrounding water, when this happens the plants may die off very rapidly. Different types of algae differ in their mineral requirements, a bloom of one species may thus often be succeeded by a bloom of another. Diatoms, for instance which live surrounded by capsules or boxes of silicate, need more silica salts in the water than other one-celled algae. The amount of salts available particularly nitrate and phosphate limit the growth of any species. The population of zooplanktonic animals which graze upon the algae follow a similar pattern, when food is abundant the population increases rapidly, when the food supply fails the animals die.

In addition to the animals which never grow much larger than a pin head the plankton includes the floating eggs of many species of fish and other aquatic animals. It also includes the young forms into which these develop when the eggs hatch, these young forms, known as **larvae,** are often very different in shape from the adult, in some animals the **larva** goes through several changes of form before the final one which resembles a tiny adult. Zooplanktonic animals prey upon one another as well as feeding upon the phytoplankton, so the number of adults produced as a result of spawning will depend on the availability of food as much, or even more, than on the number of eggs laid. The production of an excessive number of larvae could in fact be a disadvantage in some circumstances, for if competition for food becomes too intense large numbers of larvae may be weakened and die.

When planktonic and other animals die they sink towards the bottom, many reaching it and disintegrating there, in deep water therefore nutrients are constantly lost from the upper, productive layers. In a deep still lake these nutrients could be lost to the production cycle. Future production would then depend on the nutrients washed into the lake by rain or brought in in solution by inflowing streams. Under most conditions, however, the nutrients are returned to the surface by mixing of the top and bottom water. Currents produced by wind action on the surface of the sea and wave action bring about mixing. In some places the water is rolled by wind action so that the deep cold nutrient-rich water is brought to the surface by an upwelling of the bottom water. Currents flowing from the North and South poles also bring nutrient-rich water with them and where the water is enriched in this way planktonic growth, and therefore fish growth, are rapid and productive fisheries result. Mixing of the top and bottom layers of the water is more efficient in shallow areas than deep ones, ponds and shallow lakes are therefore generally more productive than deep lakes. Coastal areas benefit from the run off of water from the land as well as from the mixing of water layers which takes place there, the area over the continental shelves thus produces more fish food and better fishing than the open oceans. In the open ocean and in large lakes an upper, warm, layer of water often exists for most or all of the year, over a colder, denser, layer of water. The point at which these layers meet is known as the **thermocline.** It acts as a barrier to the lower layer for many fish species, for the lower layer has no plants to produce oxygen and no opportunity to add to its oxygen store by contact with atmospheric air, therefore it is not only cold but has little oxygen dissolved in it.

In some of the deep African freshwater lakes (e.g. Lake Tanganyika and Lake Malawi) mixing of the bottom and surface does not occur, the water is permanently stratified with the slightly warmer surface water floating on top of the deeper cooler water. Nutrients moving down from the surface layers are locked in the deeper layers. Because of the lack of circulation the deeper waters are often deficient in dissolved oxygen and are unable to support fish life. The surface layers will depend on run off from rivers to supply nutrients and production of plankton and, therefore, fish may be very small. If the stratification in the lake were to breakdown and the surface and deeper water were to be thoroughly mixed many of the fish and other organisms in the lake would be killed by the lack of oxygen in the water from the deeper layers. Mixing would re-cycle many nutrients and once re-oxygenation had occurred, fish production would be significantly increased.

Cataloguing plants and animals

If you look at the fish caught in a beach seine or trawl net you will see that the catch includes a mixture of different sorts of fish of varying shapes, colours, and sizes. The catch can be sorted into piles of recognisably similar fish, red snappers are obviously different from golden snappers and both are different from sardines or groupers. These different sorts of fish vary not only in their shape and colours but also in their way of life. If we study the way in which they live we find that they eat different things, live in different places and grow at different rates to reach different sizes. We also know that the eggs produced as a result of the mating of two fish of the same kind develop into young fish which grow up to be similar to their parents.

Animals which are alike in their appearance and habits are said to belong to the same **species.** A species is sometimes defined as a breeding unit which means that only fish of the same species would be able to breed together. For many sorts of fish this would be an accurate definition, but in a few cases the fish which are referred to as one species can interbreed with others of a different species. This happens only between species which are very similar to one another, carp cannot breed with *Sarotherodon* or sardines with groupers, but some species of *Sarotherodon* can inter-breed with one another and in this case the off spring are not exactly like either of the parents. Fish bred from different species are called **hybrids** and tend to show a mixture of the characteristic features of the parents. Very often hybrids are not fertile and cannot produce further generations.

In any country the various species of fish are given local names. Naturally enough the same species is given different names in different countries and in many cases the name varies in different parts of the same country. This would make life very difficult for scientists who want to be able to discuss their work with other scientists in different countries. Discussion is made easier by the fact that fish, like other animals and plants, are catalogued and each is given a Latin name. In fact each has two names, a **generic** name always spelt with an initial capital letter and a second, **specific** name. A group of fish which have similar shapes and coloration and behave in similar ways is called a species, groups of species which are similar in form and habits are called **genera** (singular, genus). Thus *Sarotherodon* is the name of a group of fish, *Sarotherodon mossambica* and *Sarotherodon esculenta* are species of the same genus. Since different authorities have sometimes examined the same species at different times and awarded different names the name of the authority is often given thus: *Sarotherodon mossambica* Peters. Genera which have some features in common are grouped in **families,** thus *Sarotherodon* and *Haplochromis* are two genera of the family Ciclidae, the cichlid fishes. Families are grouped in **orders** and orders in **classes.** The class Pisces, or fish, is divided into sub-classes of which the cartilaginous fishes and the bony fishes are the only living examples. Classes are arranged in larger groups called **phyla** (singular phylum), fish are grouped with other animals having back-bones in the chordate animals or **chordata,** a group which includes **amphibia** (frogs, toads, and similar animals) **reptilia** (snakes, turtles, crocodiles) **avia** (birds) and **mammals** (man, antelopes, cows, pigs, dogs, horses and whales). Each of these classes is sub-divided in the same way as are the fishes.

Other phyla of importance to fisheries are the **mollusca** which includes snails, oysters, mussels and similar shell fish and also octopus and squids; the **arthropoda** which includes insects, crabs, lobsters and shrimps; and the **protozoa** which are single celled animals dwelling in the plankton and on the bottom. The various animal phyla are referred to as the animal kingdom, the plant kingdom is divided up in a similar manner so that each known plant and animal has its own name and place in the catalogue.

The study of these catalogues is called **taxonomy** and the scientist who engages in this is called a **taxonomer** or **taxonomist.** When a new species is discovered a description is written and it is given a Latin name. The specific name is sometimes descriptive and may give some information about the plant or animal, thus lacustris — a lake dweller; microcephalus — small headed; rufescens — reddish; mossambica — found in Mozambique; rukwhensis — found in Lake Rukwha.

The names of the fishes which have been found in different parts of the world are given in **check lists** which give the local names as well as the Latin ones and sometimes include notes on the habits of the various species as well. Sometimes it may be possible to identify a fish from such a check list but more usually one must refer to a book which gives a **Key** to various species. A Key lists various features of the fish described in it and enables the skilled reader to examine a fish and determine the family, genus and finally the species to which it belongs. The visible differences between two similar species are often very small even when the fish has different habits. It is therefore difficult to produce an absolutely accurate Key which would be simple for non-scientists to use. The books often include line-drawings, photographs and coloured illustrations. In some cases these enable one to identify a fish with some accuracy, in others, even a trained fisheries biologist may find identi-

fication difficult and may send fish he has caught to a taxonomer who specialises in a particular group of fishes.

Once you know the specific name of a fish it is possible to discover a great deal about its habits, where and how it lives and how it may be caught and processed by referring to published text books and scientific papers.

FISH BIOLOGY

External features

Figure 10 shows the features which can be seen when a freshly dead typical bony fish is examined, Figure 11 shows the features of a cartilaginous fish, a shark. The skin of both is covered with scales, in the bony fish these are flattened plates, in the shark they are spiny and make the surface rough to the touch, the spiny scales are in fact like small teeth. In the bony fish the numbers and positions of the scales are regular and may be used as a help in identifying the species. In the cartilaginous fishes this is not so, there is no regular scale pattern. This is one of the differences between bony and cartilaginous fish, however the main difference is that in the sharks and rays the skeleton which supports the muscles and protects the organs is made from cartilage which is relatively soft, whereas in the bony fishes the skeleton is stiffened by the addition of calcium phosphate and other salts so that the bones are hard and rigid.

The scales offer protection from wounding and also act as a barrier to the entry of disease-causing organisms, they are embedded in the skin which acts as a boundary layer between the fish's body and the surrounding water. The skin contains special cells which secrete mucus, a slimy substance which makes the fish slippery to the touch. The mucus layer is thought by some people to act as a lubricant which makes the fish slip more easily through the water but this rather doubtful, it probably does lubricate the individual scales so that they move easily as the fish bends, and probably also has a protective function in preventing the entry of disease-causing organisms and parasites.

Fish are generally shaped so that the whole body is streamlined and moves easily through the water, the more rapid swimmers are better streamlined than the slow moving species. Swimming is accomplished by bending the body so that the tail acts like a single paddle used over the stern of a boat in Chinese 'yuloh' fashion. The shape of the tail, or **caudal** fin, is very varied. In fish which maintain high swimming speeds for long periods, like the tunas, it is often sickle shaped, in others which swim powerfully but seek their food by making sudden dashes it is broader and paddle like, in weak swimmers it is often relatively small.

The number and position of the other fins varies a great deal in different species. There may be from one to three **dorsal fins** on the back or upper surface and a single **anal fin** on the lower surface behind the anal opening. There are two sets of paired fins, the **pectorals** which are attached to the pectoral girdle (which becomes the shoulder girdle in higher animals) and the **pelvic** fins attached to the bones which become the hip girdle in higher animals. The fins are supplied with muscles, in the bony fishes the middle (median) fins can be lowered and undulated, the paired fins can be moved out from the body and some rotation is usually possible. Much less movement is possible in the fins of cartilaginous fishes. The fins may be used as brakes, for rapid turning or for slowly swimming backwards in bony fish.

Along each side of most fish an obvious line can be seen, sometimes single and continuous and sometimes in two parts, this **lateral line** consists of specialised cells which form a sense organ, the exact role of this is not known but in all probability these cells enable the fish to detect water movements and thus assist in the formation of shoals and in detecting the presence of fish which serve as prey for predatory species.

Figure 10
A generalised bony fish

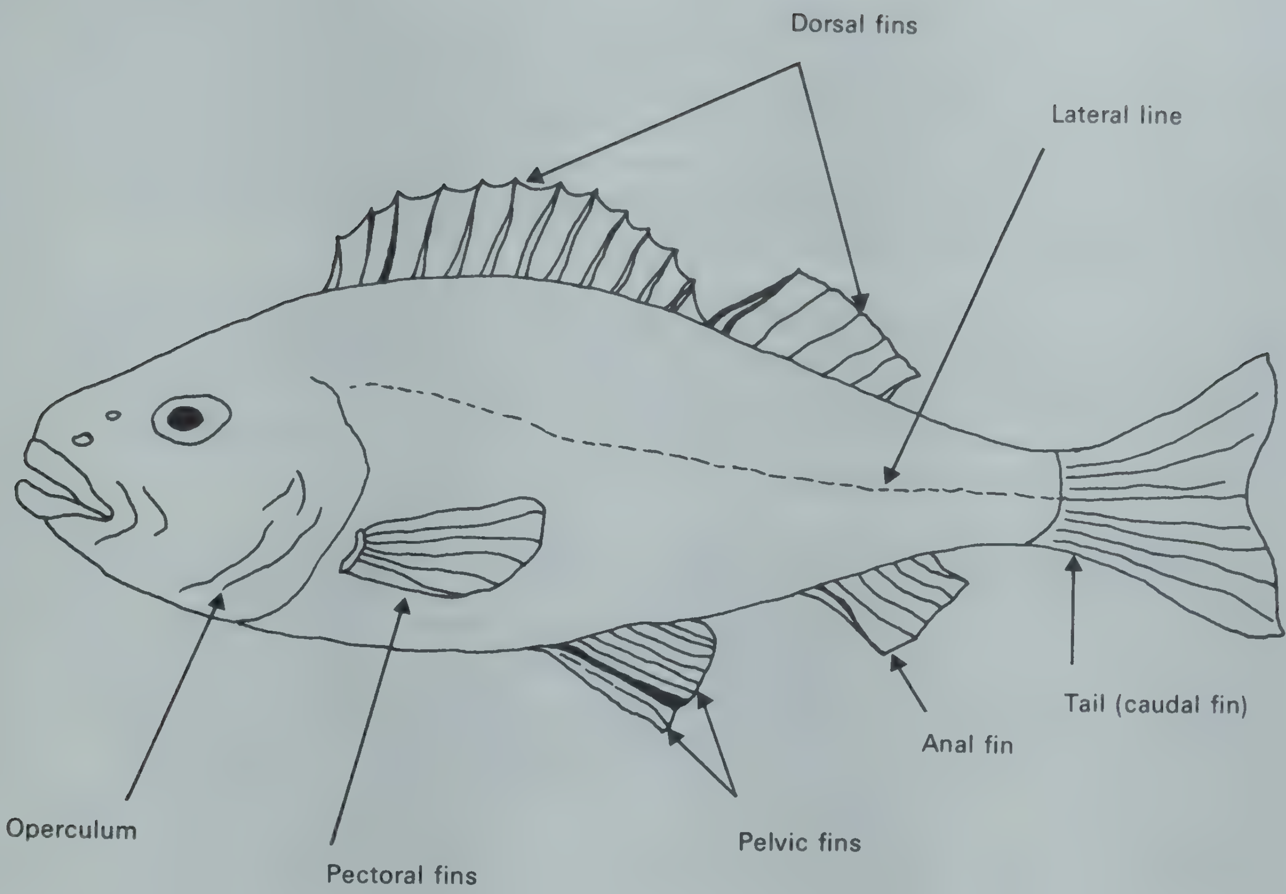
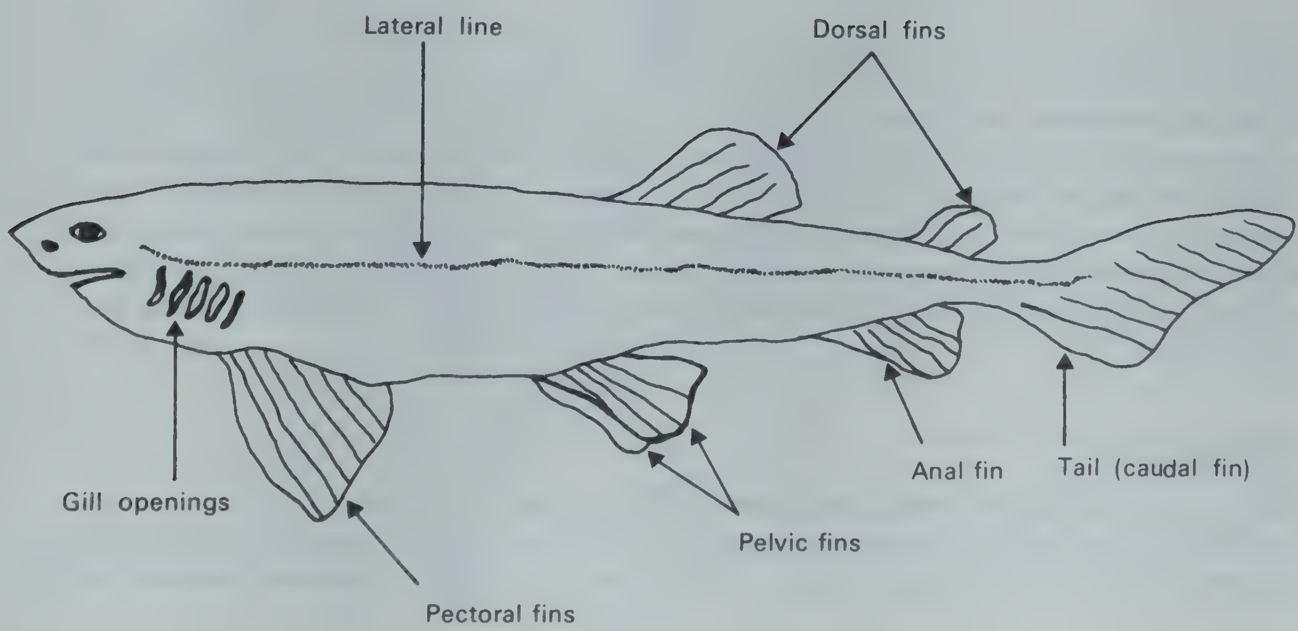


Figure 11
The shark, a cartilaginous fish



The mouth in bony fish is often at the tip of the snout, in sharks it is under the snout and in the bottom living rays it is right underneath the body. Some fish have teeth of various kinds, others do not. The type of teeth present, or their absence, may indicate the sort of food a fish takes. Sharp, powerful teeth usually indicate a predator, flat crushing teeth a diet of shellfish. Some fish are able to extend or protrude the mouth, this ability may be important in catching prey or in browsing on the plants attached to rocks.

The nostrils are represented by two or four small openings on top of the head, these open into water filled nasal sacs. The sacs are lined with sensitive cells which enable the fish to taste or smell, many fish can detect minute quantities of odorous substance dissolved in the water in which they live. They may use this ability to detect food, to find and move away from dangerous substances dissolved in the water, to locate others of their own species, or even to select a particular river in which they will spawn. Some fish also have additional sense organs in the **barbels**, these are slender finger like organs under or beside the mouth which are used to touch and taste. The whole body surface is sensitive to the touch because the skin contains many nerve endings which react to slight pressure.

Fish have eyes which are specially adapted to seeing in water and many have colour vision (many land animals cannot distinguish colours). The eyes are usually placed on either side of the head, this enables the fish to judge distances. Like other eyes those of the fishes are sensitive to movement, a still object may be ignored and a moving one investigated or avoided.

For most fish the only source of the oxygen needed for respiration is that dissolved in the surrounding water. While oxygen forms about 20% of the atmosphere the quantity which can be held in solution in water is very much smaller. A litre of air contains 200 cubic centimetres (often abbreviated to cc) of oxygen, a litre of well oxygenated water holds less than 10 cc. Fish obtain their oxygen by passing water over the **gills.** These intricate and delicate organs consist of small thin plates (**gill lamellae**) attached to and supported by the **gill rays** so that they form filaments which are attached to the bony **gill arches.** The heart pumps blood through the gills, where gaseous exchange takes place, and then on to the body tissues to supply oxygen and carry away carbon dioxide. The plates are very thin walled and the blood is thus in close contact with the surrounding water. The blood contains red blood cells, these remove oxygen from the water and return to it the carbon dioxide which is a waste product of respiration. In order to pass enough water through the gill chambers the fish must actively pump it. In the sharks the gills open to the outside through 5 to 7 **gill slits**, in bony fishes there is a **gill cover** or **operculum** on each side. Sharks have an additional opening, the spiracle, water is taken in through this and forced out through the gill slits while the spiracle is closed. Bony fish take water in through the open mouth while the gill cover is closed and pump by closing the mouth and opening the gill cover. The gills can be seen if the gill cover is pulled forward or cut off or if the gill slits of a shark are pulled open.

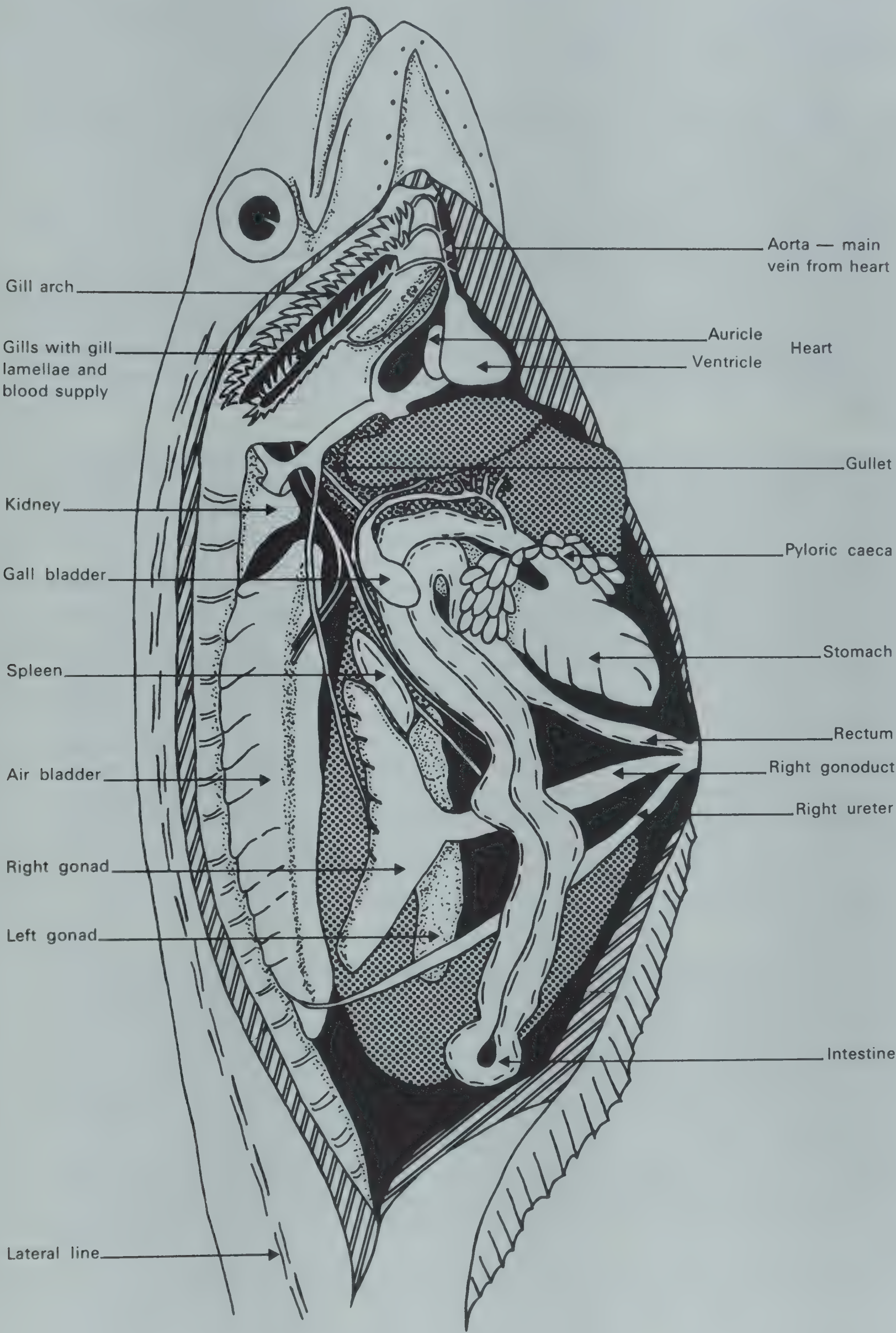
Other features which can be seen by looking at the outside of a fish are the external opening of the digestive tract, the **anus**, and those of the **urinary** and **reproductive** (breeding) systems. All these openings are found on the lower surface just forward of the anal fin, the anus is the larger opening nearer to the head. The urinary and **genital** (reproductive) systems of female fish have a single opening, in male fish these have separate openings. These features are not always obvious in bony fish and **dissection** (cutting into pieces) may be needed before the sex of a fish can be determinded. In the cartilaginous fishes the males possess a pair of clasping organs, so sexing is easy.

Internal organs

Apart from the organs mentioned above, which must be in contact with the water, the fish's organs are protected either by the skull (brain and organs of balance) or by the muscular wall of the body cavity. The muscular wall is supported by the ribs.

Figure 12 shows the approximate position of some of the internal organs as these would be seen after removing part of the wall of the body cavity on one side. The organs of the digestive system, the stomach, intestine, liver and gall bladder are easily recognised. The stomach can be traced forward to the gullet and mouth and the intestine backwards to the anus. In some fish the intestine has a number of soft finger-like appendages near the point where it joins the stomach, these increase the surface area. In some fish the stomach is straight, more usually it is U-shaped, in a few fish it is absent, however, it can usually be distinguished as a separate organ. In

Figure 12
Dissection of bony fish to show principle internal organs



Source: Adapted from Saunders and Manton (1972)

most cases there is a muscular ring at the point where it leaves the intestine, this permits the closure of the stomach so that food is released to the intestine only after partial digestion in the stomach. The liver is a reddish-brown organ consisting of several lobes from which a number of small tubes lead into the gall bladder. This is a green coloured sac from which another tube leads into the stomach, the gall bladder stores the chemicals produced in the liver which are used in digestion.

The intestine is a thin walled tube often more or less coiled, the length of the intestine depends on the fish's feeding habits. Flesh eaters have short intestines, flesh is mainly proteins rather like the fishes own body so digestion is relatively simple. Plant eaters have longer intestines as carbohydrate digestion is a longer, more complicated process. The walls of these tubes are muscular so that food can be forced along by alternate contractions and relaxations of the muscles at different points. Most fish swallow their food whole, entire fish may be swallowed or large pieces of fish taken in, sometimes the hard outside parts of food such as shell is broken by crushing in the mouth. Herbivorous fish may rasp plants to pieces with special teeth in the throat but smaller foods are swallowed unbroken. This sometimes permits even small particles which enter the digestive tract to pass through it undigested, this happens when the fishes digestive juices cannot dissolve the outer walls of the particle.

The task of the digestive system is to break down the substances taken in as food to simpler substances. These substances enter the blood circulation and can be used by the fish for respiration, (the process which provides energy) or for building new tissues or repairing worn ones. The internal transport system of the fish's body is provided by the arteries and veins which carry the blood, the blood can carry only liquids, digestion must therefore reduce foods to water soluble or fat soluble substances which can be carried in the blood to the sites where they are needed. The substances we call foods are divided into three groups: the fats or oils, which consist of carbon, oxygen and hydrogen molecules linked or bonded together in a particular manner; the carbohydrates which also consist of carbon hydrogen and oxygen molecules bonded in a quite different way; and the proteins which consist of carbon, hydrogen, oxygen and nitrogen. The carbohydrates include simple and complex sugars and starches, these are used as sources of energy, proteins are used for tissue manufacture, fats are used for energy production. Proteins can also be used as an energy source, but fats and carbohydrates cannot be used for tissue manufacture. Most carnivorous fish consume a high protein, low carbohydrate diet and proteins in the food provide the main energy source. Following digestion the simpler substances produced are absorbed by the walls of the intestine and then pass into the blood stream.

Digestion is accomplished by chemicals called **enzymes**. Enzymes are organic catalysts, catalysts are substances which speed up chemical reactions without actually taking part themselves, they remain unchanged at the end of the reaction. Enzymes are fact proteins, each enzyme works best at a particular temperature and in particular conditions of acidity of alkalinity. Because they are proteins enzymes can be changed by heating, (denatured) just as meat is changed by cooking. Each enzyme has a specific task to perform, for digestion is not completed in a single step. Starches are converted to complex sugars and these to simple sugars. Proteins, which consist of very large molecules, are first converted into smaller molecules called peptones or peptides, these are then converted into amino acids the molecules of which are still smaller. Amino acids are conveyed to other parts of the body where they are reassembled to form new proteins and used to build new tissues. Fats are mixed with water to form an emulsion and then converted to soap like products which are soluble in water.

The food is swallowed by convulsive movements of the gullet, when it reaches the stomach it is surrounded by the **gastric juices** which contain a number of enzymes, of which **pepsin** is an example. This group of enzymes work best in an acid medium and the gastric juices contain hydrochloric acid, protein digestion commences in the stomach, proteins being converted to peptones. The muscle ring closing the stomach then relaxes and the food is passed to the intestine, where it is mixed with bile from

the gall bladder. The bile contains salts in an alkaline medium which break up the fats into droplets, or emulsify them. The pancreas produces enzymes which work best in an alkaline medium and the pancreatic duct often joins the bile duct before they make a common entry into the digestive tract. These enzymes continue the digestion of the food. One enzyme, trypsin, converts peptones to polypeptides, another, erepsin, converts these to amino acids. Carbohydrates such as starches are similarly converted to simpler substances. Much of the food of herbivorous fish consists of cellulose, a complex carbohydrate, it is likely that the digestion of this substance is accomplished by tiny animals and bacteria living in the intestine, rather than by the fish's own enzymes.

The process by which the relatively simple end-products of digestion are absorbed into the body is called **assimilation.** Some assimilated products are used at once for energy production in the muscles which enable the fish to swim and carry out other movements, some are used for repair or replacement of worn out tissues or for building new ones. Some products are stored to meet future needs, some carbohydrate is stored as glycogen or animal starch in the liver, some carbohydrate is converted to fat and this together with fat eaten as such is stored in the muscles or in special fat depots. Well fed fish often contain large quantities of stored fat. Some fish such as sharks store fat as oil in the liver.

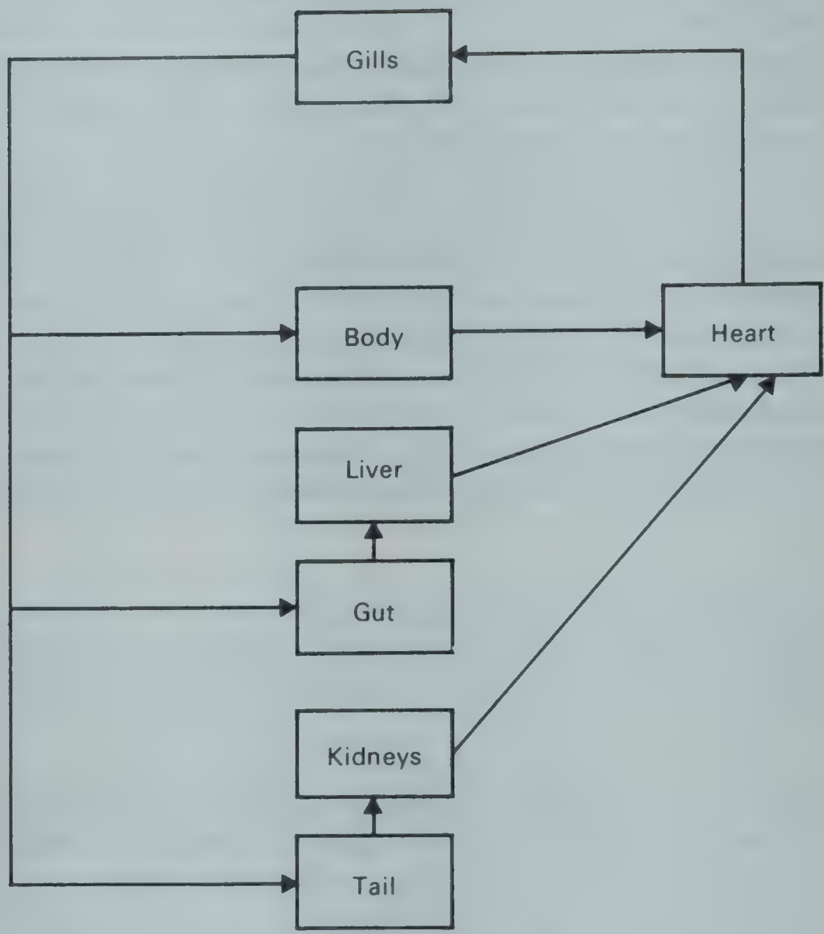
Undigested food and partially digested food are voided or vented through the anus or vent, this waste matter is known as **faeces.** The faeces contain many bacteria and also particles ingested accidentally with the food such as sand grains and pieces of coral.

The heart, which is a pump consisting of special muscular tissue, lies in a chamber protected by the ribs and separated from the rest of the body cavity by a thin wall. The heart, together with the tubular blood vessels forms the transport system; biologists refer to it as the vascular system. The medium of transport is the blood, this is a liquid tissue consisting of a pale yellow fluid, the **plasma,** and red and white cells known as **corpuscles.** The red cells are plate-like and contain a substance known as **haemoglobin** which can take up or release oxygen under different conditions. Oxygen is collected at the gills and carried to the tissues which need it for respiration. The white cells have no definite shape, their task is to protect the animal from various diseases. The plasma may contain a wide variety of organic and inorganic substances at any one time, these include salts, proteins, amino acids, sugars, fats and excretory (waste) products.

Blood vessels which carry blood from the heart to other parts of the body are called arteries, those which carry blood back to the heart are called veins. The heart pumps blood to the gills, where it is oxygenated and then passes through arteries to the head or to the various organs of the body, including the muscles. The organs remove oxygen from the blood as it is needed, and their products, such as carbon dioxide, digested foods and secretions are given up to the blood which proceeds by way of the veins back to the heart. All parts of the body must receive a supply of blood because all need a supply of oxygen and because the cells which form the tissues are constantly being replaced as they become old, or added to as the fish grows. The liver receives food substances from the digestive system as well as arterial blood. The kidneys receive veins from the muscles and other parts of the body in which there are waste products, but they also receive a supply of oxygenated blood from the gills. Figure 13 illustrates in diagrammatic form the way blood circulates in a fish.

The **kidneys** are the organs responsible for the removal of waste matter containing nitrogen, which is passed out of the body as urine; the kidneys together with the tubes which carry away this waste form the **renal system.** In mammals the kidneys are typically bean-shaped, in the fish they are long tubular organs lying close to the backbone. In some fish the two bodies unite to form a single organ. The kidneys contain masses of coiled tubes closely associated with tiny blood vessels, the coiled tubes lead into tubes or ducts which unite to form a larger tube which leads either to a urine storing bladder or directly to the exterior. The coiled tubes are sometimes enclosed in capsules, sometimes not. Urine consists of a dilute solution of ammonia,

Figure 13
Blood circulation in a bony fish



mineral salts and urea in the bony fishes, in the cartilaginous fish urea is retained in the body. In the tubes nitrogenous waste is removed from the blood while other, useful, substances are retained.

Living in water causes problems both for marine and for freshwater fishes. Sea water contains about 3.5% salt (usually the salt content is referred to parts per thousand or ‰ thus, 35 ‰). Fresh water contains very little salt. The blood of marine bony fishes contains about one-third as much salt as sea water, that of fresh water bony fishes about one-quarter as much salt as sea water. The salt water surrounding bony fish living in the sea draws water from the fishes skin cells, they are thus in danger of losing too much water from their bodies. To overcome this they drink sea water and excrete salt from the gills as well as in the urine. Their gills are also able to excrete some nitrogenous waste such as urea. The cartilaginous fish retain urea in their bodies, their blood salinity remains above that of sea water.

Few cartilaginous fish inhabit fresh water, those that do must constantly remove water from the body and urine production is high. Fresh water bony fish have the reverse problem of their marine relatives for their bodies are constantly absorbing water, urine production is therefore copious and the urine dilute, salts must be obtained from the food.

All fish have the problem of keeping the body at the desired level in the water. Sharks are heavier than water and tend to sink, and so must swim constantly in order to maintain their level in the water, a resting shark sinks slowly and rays seldom move off the bottom. The bony fishes have solved this difficulty by developing a **hydrostatic organ** known as the **swim bladder** (air bladder, gas bladder, sound or maw). This is a gas-filled sac which lies close to the backbone, the shape varies from nearly spherical to long and cigar-shaped. In some species the bladder is lobed, sometimes it is closed, sometimes it opens to the gut. The inner surface is well supplied with blood vessels and glands which secrete gas to inflate the bladder, fish with open

bladders sometimes swallow air at the surface to inflate the bladder. Gases can be removed by the blood vessels when the fish needs to reduce the size of the bladder. A fish which rises to a higher level in the water needs to become more buoyant and the bladder is inflated, one which sinks to a lower level needs to be less buoyant and gas is withdrawn by the blood vessels or expelled through the mouth. Less buoyancy is required to float in salt water than in fresh so sea fish generally have smaller bladders than their freshwater relatives. Some bony fish have lost their air bladders or have only very small ones and the mackerels and tunas, like the sharks, need to swim constantly to maintain their level in the water.

Control of activities and body functions

In order that the complicated body of a fish may function effectively a communication system is required so that movements and functions are coordinated. The 'message-passing' system consists of a nerve centre, the brain, and thin white cords called nerves containing many nerve cells which radiate from the brain to all parts of the body some being collected together to form the spinal cord. The nerves include receptor units which pick up sensory messages and effector units which, on receipt of a message, cause a reaction in the organ they serve. Messages may be passed to the effectors via a short chain of nerve cells or direct from a receptor. This permits rapid or **reflex** actions as, for instance, when the skin touches an object and the muscles twitch. The brain is not involved in such reflex actions which are involuntary or unconscious. Messages may also pass through a much longer chain of nerve cells from a receptor to the brain and then back to an effector. This permits conscious action in response to a stimulus as, for instance, when a fish smells food and then carries out a search for the source of the odour. The most important parts of this system, the brain and spinal cord, are protected by bone and cartilage, the brain being housed in the skull and the spinal cord in the backbone.

The nerves consist of bundles of fibres each of which passes messages in one direction only, the way in which the messages are passed is not perfectly understood. It has been known for many years that muscles can be caused to contract by passing electric currents through their nerves and the electric current generated in a nerve can be measured. It seems likely that the impulses passed are electrical and that these impulses are generated by chemical batteries.

Impulses may be started in a variety of ways, thus the cells forming the retina (the layer of cells lining the eyes) are light sensitive, those in the lateral line skin organs are pressure sensitive, those in the olfatory organs (with which the fish smells) are able to react to chemicals dissolved in the water giving the fish a sense of smell. Most probably almost all the parts of the body are more or less sensitive to chemical stimuli, thus the presence of food in the stomach causes the manufacture and release of enzymes.

In addition to the nervous system of control there is a chemical system which works in association with the nerves. This is the **endocrine** system of ductless glands, these are the bodies which manufacture the chemical messengers known as **hormones** but which do not have collecting tubes, or ducts, as, for instance, does the pancreas. Hormones are released directly into the blood-stream, they perform a variety of regulating functions such as controlling growth and some body functions. The other part of the gland system is the exocrine glands, these glands include the pancreas, which often forms a cap on the gall bladder in bony fishes and which produces insulin. The pancreas is a composite gland, part of it produces digestive enzymes which are carried to the intestine by a duct; another part produces insulin which is released directly into the blood-stream. Insulin is the chemical substance which controls the sugar chemistry of the body. Another hormone, thyroxin, produced by the thyroid gland, controls the rate of body chemistry. Adrenalin, produced in the adrenal glands which lie near the kidneys, has several marked effects on the body when released. Adrenalin prepares the body for emergency, it increases the rate of heart beat, increases the amount of sugar present in the blood (so that a store of potential energy becomes available) and it also affects the eye muscles. Adrenalin may be released as a result of fright and enables a fish or other animal to take rapid

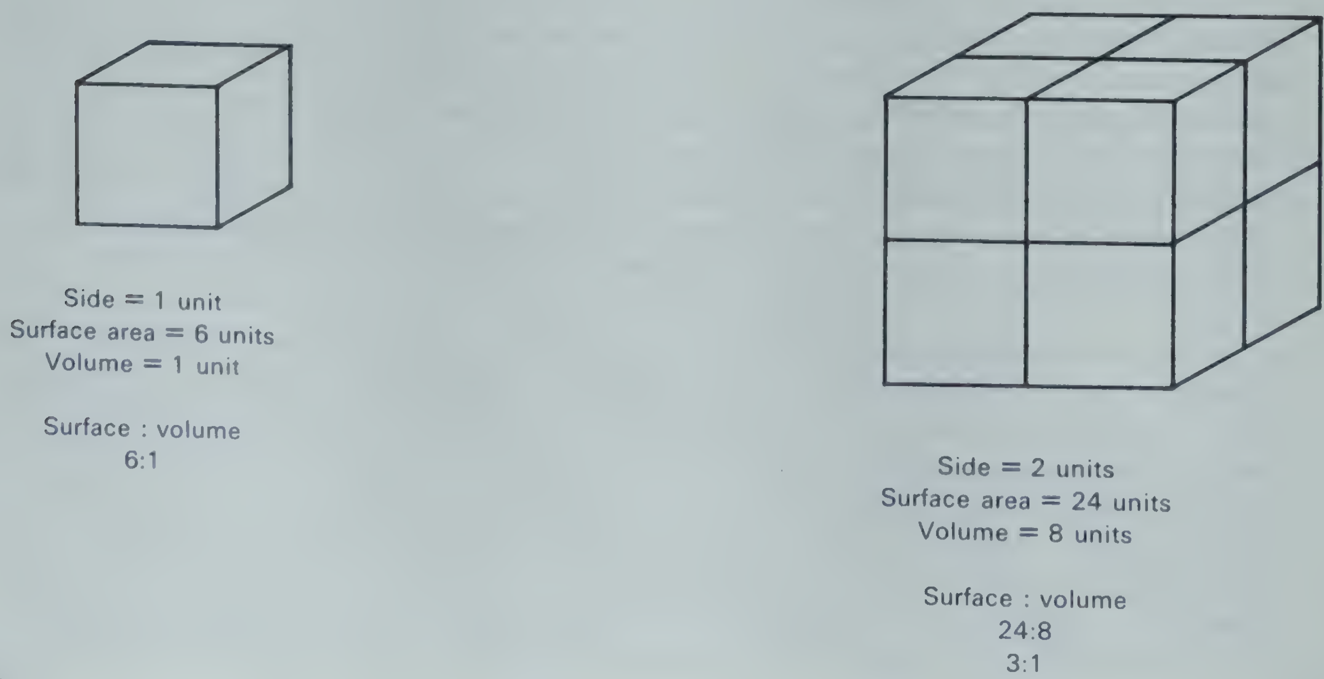
action to protect itself. The pituitary body, which is a fairly large gland lying in a pit near the base of the skull, produces a large number of hormones. These include a number of growth hormones and others which stimulate the reproductive organs. The **gonads** or sex organs also produce a number of hormones as do a number of other parts of the body, the cells lining the intestine for instance produce a secretion which causes the release of pancreatic juice. The chemistry of the body is thus under the general control of the ductless glands, failure in any one of these may throw the activities of the body out of balance and lead to disease or even death.

The processes of growth and reproduction

All the various organs and tissues of the body are made up of units called **cells,** the simplest animals consist of single cells but an animal such as a fish is composed of millions of these units. The cells of the various tissues are of different shapes and sizes and perform a variety of different functions. These functions are essentially chemical, cells must be able to communicate with one another, but much of their activity, such as the interchange of chemicals takes place at the surface. Cells can grow in size but there is a limit to the amount of growth that can usefully take place because a large cell has a relatively smaller surface area to volume ratio than a small cell. This is illustrated in Figure 14. A cube with a side one unit in length has a volume of one unit and a surface area of six units, a cube of side two units has a volume of eight units and a surface area of 24 units, this gives a surface to volume ratio of six to one in the first case and three to one in the second. If a cell becomes too big it therefore becomes less efficient and, for animals like fish, growth in size requires an increase in the number of body cells. This process of cell multiplication is effected by division of existing cells, followed by a limited period of growth in size of each of the two new cells. When the two new cells reach the optimum, or best, size, they may divide again. Even in an animal which is no longer growing some cell division will take place, for old, worn out cells are broken down and replaced by new ones. The whole of an organ may be broken down and replaced in a matter of days or weeks. This is why all animals must include a certain amount of protein containing foods in their diet, the body cells consist mainly of protein and water, as these are replaced new protein is required. Young actively growing animals need relatively more protein in their diet than adults because they need it for making new tissues as well as for replacing worn out ones.

It is obvious that if the cells of a tissue are to multiply and produce new tissue the new cells must be exactly like the old ones, muscle cells must produce muscle cells, gland cells gland cells and so on, if they did not do so the orderly arrangement of the tissues and their functions would be lost. This is in fact what happens in a cancerous

Figure 14
The relationship between surface area and volume



tissue. There must therefore be a controlling mechanism to ensure that like produces like, this mechanism lies within the nucleus, the spherical body which controls activity within each cell. Each nucleus contains a number of long, thin, paired bodies called chromosomes, the number and shape of these varies in different animals and plants but each species has a particular number of chromosomes in each of its body cells. Each chromosome bears a number of protein molecules called genes, these are the material inherited by new cells and, indeed, by new individual animals and plants, they determine the chemical and physical nature of the individual cells and thus of the whole organism. A cell divides to form two identical cells in a process called **mitosis**, in this way each new cell receives exactly the same control system. This process involves each half of each pair of chromosomes duplicating itself, this results in two pairs of chromosomes in which each pair is identical. These pairs then divide and go to different ends of the cell so that when the cell itself divides it takes one of each of the pairs, forming two cells, each with a pair of chromosomes identical to those of the original. In the development of the specialised reproductive cells a different process known as **meiosis** takes place, in this the pairs of chromosomes are separated so that each egg or sperm carries one chromosome of each pair only, so that when the egg and sperm unite at fertilisation the body chromosome number is restored to normal. The two chromosomes of each pair are almost but not quite identical. Thus, although the body cells of any particular tissue will be alike, because they are produced by mitosis, the egg or sperm cells are not exactly like one another. The new cells formed at fertilisation are thus not exactly alike. Each new individual animal results from the division of the cell formed at fertilisation so each individual is a little different from every other. This is a matter of common observation, some men are short and some are tall, some have blue eyes, some brown. It is also a matter of observation that animals and plants tend to be like their parents, tall men generally have tall sons and so on. All that the new generation receives from its parents is a single cell from each, the two cells fuse, the new cell divides into two, then into four, eight, sixteen, the process continuing until the new individual reaches adult size.

The reproductive system

The union of two cells mentioned above and called **fertilisation** is known as sexual reproduction. The two types of cell are known as eggs, or ova, and sperm. Eggs are produced by the female, or hen fish, sperm by the male, or cock fish. In most species the adult fish is either male or female, in a very few species the fish starts life as a male and ends it as a female, in even rarer cases eggs and sperm may be produced by the same fish at the same time.

In most bony fish the eggs are released from the body and fertilised in the water, in a few bony fish and in the cartilaginous fish sperm are introduced into the body of the female by the male and, after fertilisation, the eggs develop within the mother.

In the first case fertilisation is said to be external, in the second case internal. In some cases where fertilisation is internal the young are retained in the mother's body until they are able to swim away, in other cases the eggs are released soon after fertilisation.

If the number of fish in a given body of water is to remain at the same level each pair of fish, during its lifetime should produce two others. Young fish are vulnerable to attack by a variety of predatory animals and may die from a number of other causes such as disease or lack of food. In order to maintain their numbers in the face of these difficulties fish need to be able to produce large numbers of young to allow for the inevitable losses. The number of eggs normally produced by a given species depends on the size of the eggs, the type of situation in which they are released and fertilised and the degree to which the parents protect the young fish. Fish which live in the open ocean and release their eggs and sperm into the sea often produce millions of eggs. *Sarotherodons* (Tilapias), which guard carefully prepared nests or pick the eggs up and incubate them in the mouth produce only hundreds of eggs. Some sharks, which bear their young alive produce from four to 12 babies. Larger, older females of any species tend to produce more eggs than younger smaller individuals of the same species. The process in which eggs are laid and fertilised is referred to as **spawning**.

The reproductive organs in most species of fish are relatively simple, for their sole task is the manufacture of eggs or sperm. In live-bearing fish such as sharks the system is more complex. Adult fish sometimes have two ovaries, or egg producing organs, sometimes only one. The male organs or **testes** (singular, testis) in which the sperm are produced are commonly paired. In some cases the ovaries or testes have tubes or ducts which unite to form a single duct which leads to the outside, in other cases the eggs are shed into the body cavity, though testes in the same species are ducted. In some species the ovaries will contain eggs in various stages of development and spawning may then take place several times a year, in other species the eggs all ripen at once and spawning takes place at longer intervals.

The size of the individual egg varies considerably with the species, generally the range is from one to four millimetres in diameter. Fish eggs are generally spherical or oval in shape and have no means of movement, some float in the water, others sink, some are sticky and are laid so that they adhere to the bottom, or to weeds. Each egg consists of a single nucleus embedded in a protoplasmic layer called the germ layer and of a food store for the young developing fish called the yolk. Eggs which float also often have a drop of oil which acts as a buoyancy bag. Most eggs take up water and swell after release.

A sperm consists of a small more or less spherical or oval head which contains the nucleus and a tail with which it swims actively, it has no food store equivalent to the yolk. Sperm are very much smaller than eggs and since many must die in their search for an egg to fertilise they are produced in much larger numbers than eggs. Sperm are referred to collectively as **milt**.

When the eggs and milt are shed into the water the sperm swim actively towards the eggs, presumably attracted by a chemical shed into the water by the eggs. When a sperm reaches an egg it bores its way through the shell which then hardens thus preventing the entry of other sperm. The tail remains outside and the nuclei of the egg and sperm unite in the process known as **fertilisation.** At this point the adult number of chromosomes is restored and the sex of the future fish determined, sex is determined by the chromosomes received from the male parent, the sperm include either a male or female determining chromosome, the eggs are all alike and cannot determine sex.

Larval development

The young fish which develops from the fertilised egg is known at first as a **larva** and early development is called larval development, this stage in the life of the fish being referred to as the **larval stage**. Larvae develop inside the thin shell of the egg. Soon after fertilisation the newly formed nucleus divides into two cells, these then divide again and the process becomes almost continuous. At first the cells formed all look alike but after a period of a few hours the mass of cells forms a ring with a thickened portion, this portion grows and forms the body of the larval fish. At a very early stage it is possible to distinguish the head and tail ends and the first muscle segments. The eyes are formed early and before the end of the second day the heart has formed and can be seen to be beating, soon the fins can be seen and the other organs are formed in a regular order. During this time of development the yolk is gradually used up, but most fish are born (the eggs are said to **hatch**) at a time when there is still some yolk remaining as a food store.

The various organs are formed from cells which at first show no difference in form from the other cells, by the activity of chemicals called organisers. The organisers are formed in a group of cells which become specialised and form a gland.

When larval development within the egg is complete an enzyme is produced which weakens the shell and the larva emerges, usually tail first. The time which elapses between fertilisation and hatching varies from a few days to several months. Since, this is, fundamentally a series of chemical reactions, development is faster at high temperatures than at low ones. Larger eggs tend to develop more slowly than small ones and eggs which have larger yolk stores tend to produce more fully developed larvae than those which have smaller stores.

Newly hatched larvae, known as **alevins**, are from two to twelve millimetres long. The alevin does not feed at first, it uses up its yolk sac, when this is gone and preferably before that, the alevin must find a supply of suitable food. If it does not, it dies. This is a critical time in the life of the fish and many larvae die without feeding at all. At this stage the larvae form part of the zooplankton and are thus fed upon by predatory animals. The alevins which start to feed and avoid capture by predators commence to grow and gradually assume the adult form. The type of food taken often changes as the larva grows, at first it needs very tiny food particles and therefore can eat only the smaller planktonic plants or animals, at later stages it is able to take bigger particles and finally it assumes the feeding habits of the adults of the species.

At each stage growth and survival depends on the larva finding a supply of suitable food. The survival of a particular brood of larvae thus depends on such factors as the supply of nutrient salts in the water, adequate sunlight, and, in some cases, rainfall. If the eggs are laid in the wrong place or at the wrong time few or none of the brood may survive. This is why some fish produce such enormous quantities of eggs, many biologists suggest that the number of fish spawning in a particular year is of less importance in providing an adequate stock for fishing than good conditions for larval survival.

Selection of breeding time and place

Successful reproduction of the stock of fish depends in the first place on the meeting of male and female fish. Species which swim together in groups (schools or shoals) obviously have an advantage here over solitary fish, for a typical school consists of male and female fish. Schools usually consist of a group of fish of similar age and size so that all are ready to breed at the same time.

The food requirements of the young and adult fish are often quite different, many species overcome this difficulty by moving before spawning from their own feeding grounds to areas where food for young fish is available. Such movements are referred to as **migrations,** the fish are said to **migrate.** Other species migrate from adult feeding grounds to areas where the bottom is suited to their egg laying habits. Thus salmon, which feed in the open ocean, run up to the gravel bedded headwaters of rivers in order to lay their eggs in nests in the river bottom. The young fish make their way down to the sea. This is also an effective way of bringing the sexes together. The various tropical shads have also evolved the habit of moving into the rivers to spawn; many tropical carps spawn in the well-aerated waters of the upper reaches of rivers, lake dwellers as well as river dwelling species having evolved this habit. Such migrations take place regularly at particular seasons, the gathering spawning stock provides easy fishing.

Many lake dwelling species move into the shallow fringes of the lake for spawning, the eggs of some are attached to rooted plants which can live only in the shallows, these plants also provide hiding places and food for the young. The eggs of shore dwelling marine species are often found attached to the bottom rocks. Other lake dwellers such as the *Sarotherodons* and some catfish make nests on sandy bottoms. The nests are usually more or less circular pits and may be surrounded by a low wall, in some species both parents take part in nest building, in others the male alone is responsible. The eggs are laid in the nest and covered with milt by the male, most *Sarotherodon* pick up the eggs and brood these in the mouth, in other species the nests are guarded by one or both parents. The habit of mouth brooding ensures the survival of large numbers of young but during the brooding period the adults do not feed and thus lose condition.

Fish which live in the open ocean lay a relatively enormous number of eggs. Although the tunas are so important commercially, little is known of their breeding habits and early development. It is known however that vast numbers of eggs are produced and that these possess an oil globule which renders them buoyant; that the period of incubation is short and larval growth is rapid. Newly hatched tuna larvae are two to three centimetres long, larvae and fry are found in the warm water regions between

the parallels of 30° North and South, few larvae have ever been caught in deep water. The flying fish are unusual amongst oceanic fish in that small numbers of eggs are produced (less than 10,000 per fish) and the eggs have tendrils by which they are attached to floating seaweeds. Eggs, larvae and fry are thus protected from predators.

Reef dwelling fishes also show different habits. The coral living surgeon fish *Acanthurus triostegus* is reported to lay some 40,000 eggs, the fertilised eggs are buoyant and hatch in little more than a day. The larvae, at first only two millimetres long, drift away from the islands where they are spawned, the larval life lasts for two and a half months. This provides an opportunity for the species to colonise new islands or other reefs but many larvae must be lost in the open ocean. The rabbit fishes, *Siganus* spp., best known as the **cordonnier** of the western Indian Ocean, live on the reefs as adults, the young spend their first two years in the shelter of the lagoons migrating to the reefs in their third year. Some species of *Siganus* are known to produce more than three million eggs per female; the adults spawn in their fourth or fifth year. Some species of sardines and anchovies are known to produce numerous floating eggs; spawning takes place near the shore although the adults may be found far from land at other times. The young fish remain inshore where there are weak currents and eddies which enable them to stay on productive feeding grounds.

In temperate climates, where the temperature may range from below freezing in midwinter to 30°C in summer most fish breed at only one season. This is commonly in early spring just as the phytoplanktonic bloom is starting. Many cold water fish are thus in best physical condition in midwinter before spawning and in poor condition in early summer. The same species spawns at different times at the extreme north and south of its range.

In the tropics the seasons are less well defined, some fish may be found ready to spawn at any season. Thus *Sarotherodon mossambica* kept in ponds near the equator spawns the year round. Other species such as the carps which run up rivers to spawn do so at the beginning of the rainy season only. In some marine species spawning seems to be associated with the change of monsoon. Many tropical species are able to produce more than one brood a year, a fact which obviously contributes to the continuation of the species, if one brood meets unfavourable conditions and perishes, the next may survive.

Egg and sperm production is controlled by hormones, those of the pituitary body and gonads being particularly important. Exactly what stimulus is needed to induce the production of the necessary hormones is not precisely known for most species of fish. Temperature is certainly important for many cold water species, in those species which have a wide north and south range those fish living in the warmer waters may reach maturity several years before those living in the cold waters. The number of hours of daylight a fish experiences affects the production of some hormones, this again is possibly more important in temperate region fish than in tropical ones. Although it is known that both temperature and light may control reproduction in fish little is known of the effects of variation in these factors so far as the commercially important tropical species are concerned. Spawning can be induced in some farmed fish by providing a flush of clean running water through the pond or by removing individual fish and injecting an extract of pituitary hormones. Controlled breeding for fish farmers is an obvious advantage as fry can be produced as required.

THE AIMS OF FISHERIES MANAGEMENT

The population or **stock** of fish living in a body of water is never static. The number of fish present changes from day to day as some die or are eaten and others are born, the living continue to grow so there will be changes in the weight of fish present as well as in numbers. The amount of food present and available also changes constantly, but a particular body of water can be expected to produce a given quantity of food per day. It can therefore be regarded as being potentially capable of providing food for the same weight of fish. Like almost every statement ever made about living things, this one is only approximately correct. Fish use their food for the maintenance of their bodies, to supply energy and for growth. Unless the

first two demands are met no growth takes place, it is, in effect, surplus food which produces growth. Fish of the same species grow at different rates at different ages, so a population of old, big, fish would be using a large part of the food available for maintenance and little for growth while the same weight of young, small fish of the same species would need less for maintenance and thus be able to use more for growth.

If some fish die more food is left for others, when we catch fish we therefore make it possible for those remaining to grow faster. If we catch too many, those remaining will not be able to eat all the food available so some food will be wasted.

The aim of fishery management is, therefore, to remove the 'right' number of fish of the 'right' size so that the remaining stock can make the most efficient use of the available food. This is often referred to as obtaining the maximum sustainable yield; this implies not only making the best use of the food available but also leaving enough fish to breed and produce the next generation. In practice this consideration seldom arises for it would be difficult to catch so many fish as to reduce the stock below the safe level. There are exceptions to this rule too, some fish are very easily caught when on a spawning migration. The fishery for *Labeo victorianus,* a carp living in Lake Victoria became of little value following heavy fishing of the spawning stock. In 1960, 2,760 tons were caught in the Tanzanian waters of Lake Victoria, in 1961 fishing was uncontrolled and in 1962 the catch was only 97 tons.

Fish of the same species compete with one another for food. Where several species are present they usually compete for food either directly or indirectly. Thus phytoplankton eaten by one species of fish obviously cannot be converted to the zooplankton which another species would eat, plankton eaten by a mollusc is not available to any fish except a mollusc eater or to a predator which may eat any of the other fish. Because phytoplankton is converted directly to fish flesh in a plant eating fish, a given body of water can support a greater weight of plant eaters than of flesh eaters, most waters support a mixture of species. Perfect management would require a very delicate balance between available food and numbers of fish, this can never be achieved even in the smallest pond.

Reasonably efficient management requires that we know the best size of fish to catch and how many to take in a given period of time. It is impossible to catch fish of one exact size, any fishing method will take a range of sizes, nor is it possible to catch an exact number. The best that can be done is to use the information obtained by the fisheries biologist as a guide line and to frame legislation so that the catch is kept as near as possible to the 'best' level. 'Best' level because the 'right' level is continually changing, because as soon as one fish is caught conditions are altered for the remainder. 'Best' level therefore results from trying to take a long-term view and assuming average conditions.

Under day to day operating conditions it is extremely difficult to predict the 'best' level of catch, even when considerable technical information is available. The commercial exploitation of a new fish stock, or the introduction of a new fishing method, requires very careful monitoring of the catch landed. Reactions of a fish stock to fishing pressure cannot always be accurately predicted and the original estimates of 'best' catch level may need altering as information on the catch landed becomes available. Catch levels and average size of fish caught from a previously unexploited stock are, initially, quite high, but they may rapidly fall off and stabilise at a lower level. With the high cost of modern fishing gear and boats, plus the high operating costs, it is important that the investment in boats and gear takes into account that catches may level off after one or two years commercial fishing. It is better to invest at below the maximum predicted number of fishing units until the fish catch has stabilised and more accurate predictions can be made. The high operating and capital costs of sophisticated fishing boats demand high catch levels to be economically viable. Too many boats may not be able to earn a living from the resource and the catch may drop drastically if the stock is overfished. Serious overfishing can permanently damage a stock or give rise to a situation where recovery would take several years, even without fishing pressure. Obviously, any manager of a resource would want to prevent permanent damage to that resource and ideally requires to crop the resource at the optimum level.

In recent years there have been a number of cases of serious overfishing, (for example the Gulf of Thailand), and the consequences of seriously overfishing a resource can be severe. Apart from the loss of protein food to the population, many fishermen, fish processors and traders would be put out of employment. The capital investment in boats, fishing gear and landing facilities may be by a long-term loan and this would continue to require repayment. It may be possible to move the boats on to another resource, but the gear and landing facilites are less easily re-employed elsewhere.

Management decisions in fisheries require considerable information and experience if the 'best' catch levels and economic return on the investment are to result.

SHELLFISH

So far the whole of this chapter has been about the true fishes. These are sometimes known as the scale fish or fin fish to distinguish them from the shellfish. The shellfish, which include many important food animals, fall into two quite distinct groups: the crustacea, all of which have segmented bodies at some stage in their lives; and the molluscs almost all of which have hard chalky shells on the outside of their bodies. The group includes some animals which do not have these shells — the octopi, squids and cuttlefishes.

Molluscs

The edible molluscs are divided into two groups: the univalves which have a single shell; and the bivalves which have two shells. The univalves include animals such as the winkles, whelks, the abelones, the green snail and the trochus. The first two are eaten in Europe, abelones are regarded as delicacies throughout the world and also produce most attractive, ornamental shells and the green snail and trochus are still used for button manufacture because the inside of their shell has an attractive silvery sheen. The bivalves include the oysters, mussels and clams. The univalve molluscs usually feed by browsing; none of these are commonly farmed. The bivalves often feed by filtering the plankton from the water, many of these are farmed and it is possible to produce enormous weights of wet meat by farming mussels in areas where conditions are favourable.

The molluscs have well developed systems for digestion, blood circulation, and respiration. Many have a well developed nervous system and in some species the eyes are as well developed as in higher animals. Other species have very poor vision or none at all. Reproduction is sexual but some animals are hermaphrodyte, that is to say both the male and female organs are present in the same animal. Self fertilisation is rare, the animals which are hermaphrodyte usually pair, fertilisation is usually internal. In some animals, as in the European oyster, individuals function alternately as males and females. In some animals the fertilised eggs develop into larvae which are free swimming in the plankton whereas in other cases the larvae may be held in the mother's body for a considerable period. The free swimming larvae are quite unlike the parents in shape and form, often at least two forms are assumed before the young animal settles down on the bottom and commences to grow into an adult.

Crustaceans

The crustaceans include such common food animals as crabs, lobsters, crayfish, crawfish, shrimps and prawns. All of these have segmented bodies as is obvious in animals such as shrimps and crawfish but less obvious in the crabs. A common feature of all these animals is that in order to grow they must throw away their shells and grow new ones because the shell will not stretch and cannot grow. Growth thus takes place in sudden spurts, the animal multiplies its cells within the existing shell then seeks a hiding place, it then absorbs water so that the shell splits, wriggles out of the old shell and rests in a hiding place until a new shell forms. Another common feature is that in most species the mother carries the developing fertilised eggs for quite long periods. When the eggs hatch a free swimming larva emerges which is quite unlike the adult, it goes through several changes of form shedding its

skin on each occasion until eventually the final adult form emerges. Because there are so many changes of form and because the larvae, which are minute and delicate, require different types of food at different stages it is difficult to farm most of these animals. It has been done successfully in a few cases as for example shrimps, because the adults are such valuable food items it is possible to operate shrimp farms very profitably but the process requires a high degree of skill. There are, however, ancient methods of farming shrimps which do not involve raising the young from the egg. The young adults are allowed to swim into ponds where they fatten and are eventually caught. Attempts to grow the larger very valuable animals such as craw-fish and lobsters have not yet been very successful. Many species of tropical shrimp grow to maturity in a year or less, the crawfishes and lobsters are long lived but grow slowly so that farming of these seems less likely to be a profitable occupation because the risk that the animals might die in captivity is high.

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Chapter 3

Fishing boats

INTRODUCTION

A fisherman without a means of travelling on water is restricted to fishing the very small area he can cover from the banks of a river, the shore of a lake or the edge of the sea. The development of fishing craft allowed exploitation of the areas away from the shore.

A fishing boat should fulfil some, or all, of the following requirements:

1. Carry men and fishing gear to the fishing grounds.
2. Provide a stable platform to fish from.
3. Be capable of riding out normal bad weather in the area. (Obviously, the standard of seaworthiness required on a small lake will be different from that required for the open ocean).
4. Have sufficient carrying capacity for the catch, sometimes with space for processing, e.g. icing or salting.
5. Have space for carrying spare fishing gear.
6. Have reasonable speed and range.
7. Be durable.
8. Be of reasonable cost in relation to operation.
9. Have ease of maintenance.
10. In some locations the ability to launch and land through surf onto a beach is essential. (See Plate 1).

The general layout of a fishing boat, to illustrate some of the terms which will be used, is shown in Figures 15 and 16. A comprehensive list of terms is given at the end of this Chapter.

THE DEVELOPMENT OF SIMPLE FISHING CRAFT

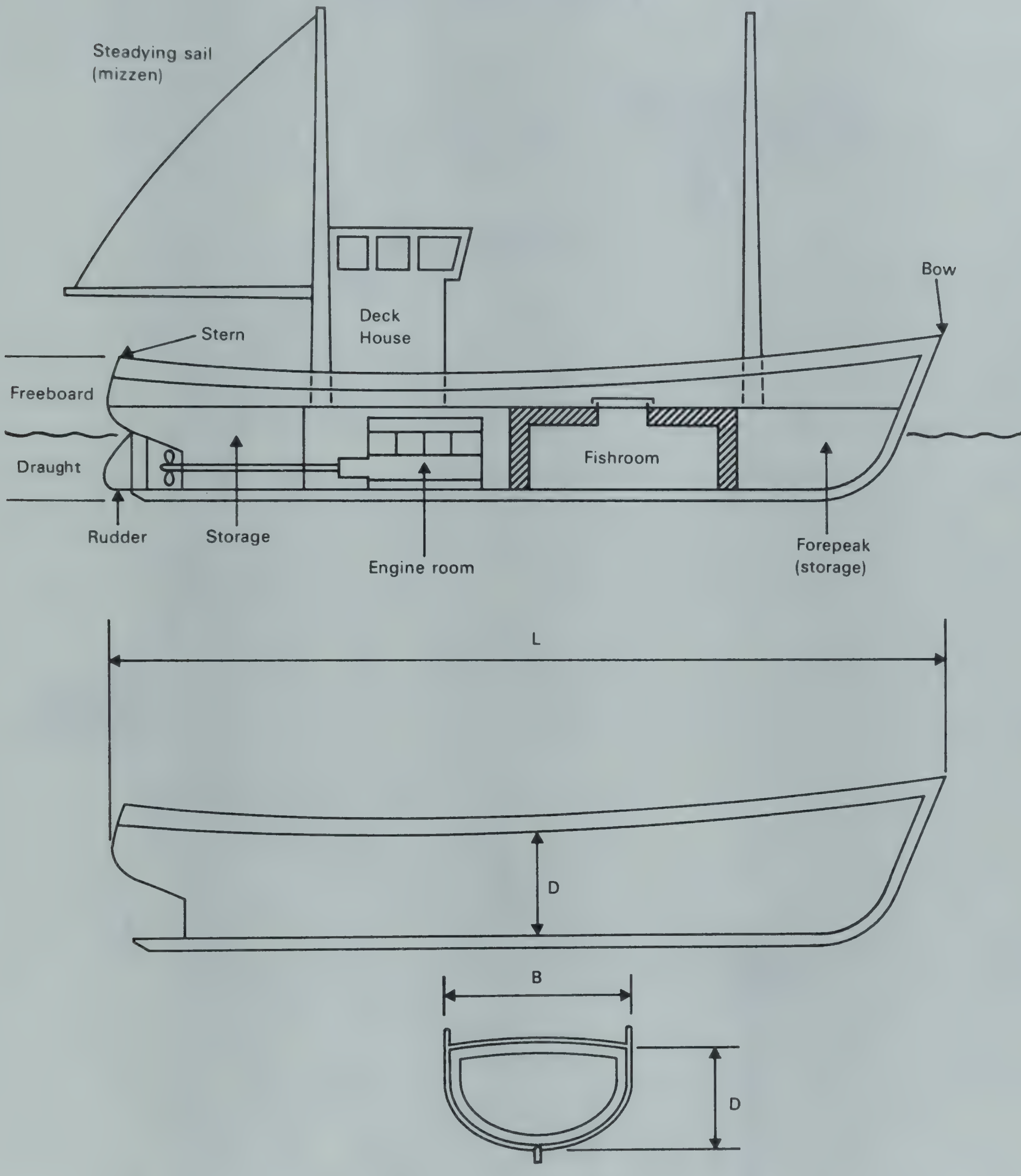
A simple raft of logs bound together with ropes probably comprises the simplest boat and in Brazil, India and Sri Lanka such craft are still used. Semi-rafts made from bundles of papyrus reeds tied together are still used on Lake Chad in Africa, on Lake Titicaca in South America and on the Arabian Gulf. On the rivers Niger and Benue in West Africa, some fishermen still use a large gourd as a float to tend gear set in the river. The gourd supports the fisherman who lies straddled across it, paddling with his hands. It is also a receptacle for any fish that have been caught. Dug-out canoes made from hollowed-out logs are still in use in many parts of the world. Freeboard and beam are increased in some cases by the addition of planking to raise the gun-whale height. Simple dugout canoes are inherently unstable and unsuitable for operation in anything but calm conditions. Various outrigger and catamaran devices have been developed, particularly in the Pacific, to improve stability and allow the

Plate 1
'Sandskipper', a fishing catamaran undergoing surf landing trials in Sri Lanka

use of sails for propulsion. Dugout canoes are also heavy for their size and have a limited load carrying capacity. Size is governed by the size of tree available, in many parts of its world large trees are not available in any quantity. Timber is a valued commodity and the fabrication of a single canoe by hollowing out a log is very wasteful. The wood cut out of the log is in small pieces and is of no further constructional use.

The next major development in the construction of boats is the use of a much lighter 'skin' of waterproof material over a framework to form the hull. Timber is cut into planks and these are fastened to a wooden framework. Construction of a boat from many pieces of timber allows for the development of hulls longer than the length of the timber. It also allows for the design of various hull shapes suited to particular needs, rather than the essentially predetermined hull shape attained from a dugout canoe. The outer waterproof skin can be made from various materials, timber being the commonest in most forms of traditional boat building throughout the world.

Figure 15
The general layout of a fishing boat and the main hull measurements



Length (L) Measured on a straight line from fore part of stem at head to aft side of outrigger or transom

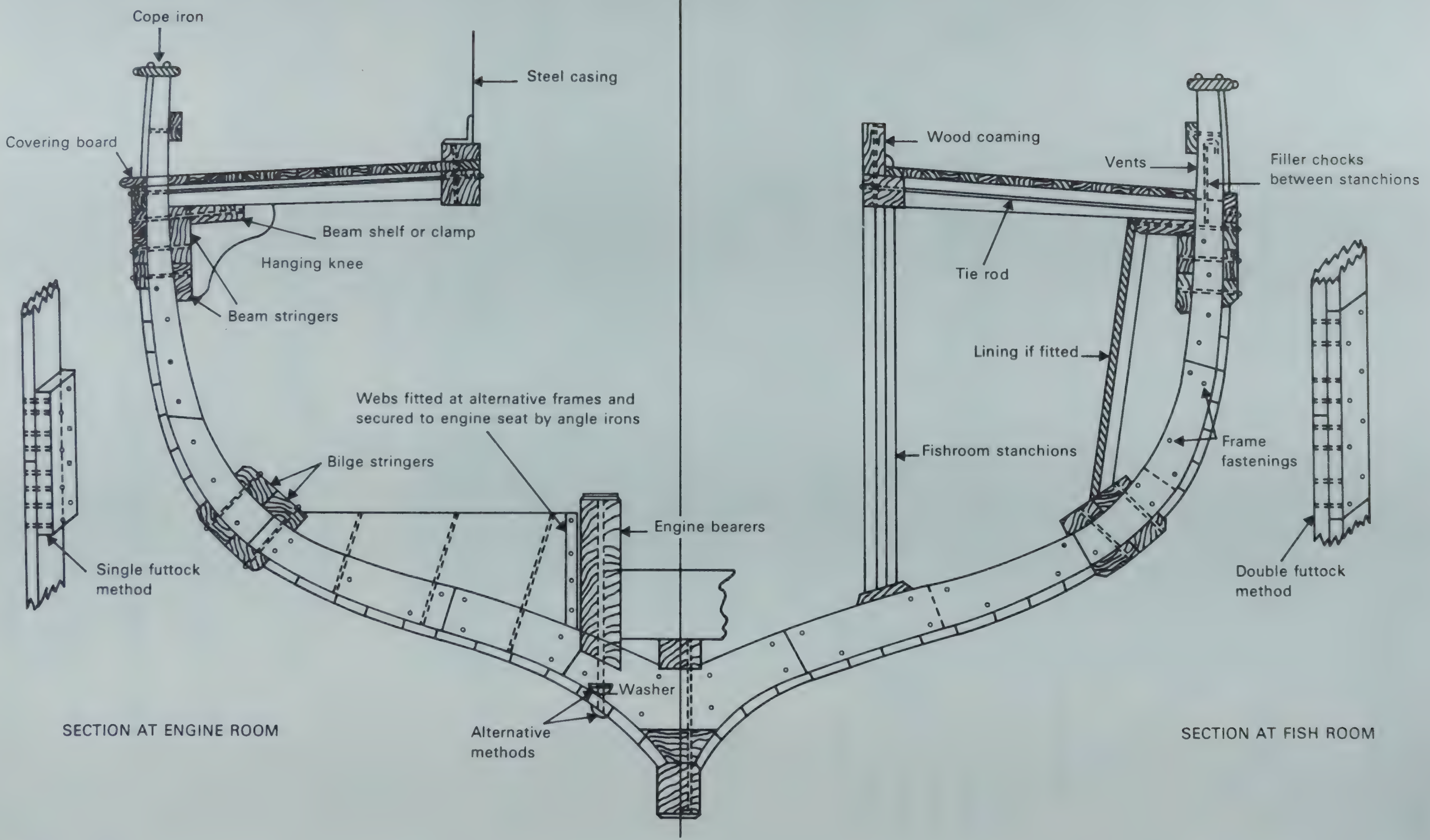
Breadth (B) The greatest breadth of the vessel measured to the outside of planking at deck level

Depth (D) Measured at the middle of the length (L) from outside of plank at the keel rabbet to top of deck beam at side

All measurements to be in metres

Source: W.F.A. 1975

Figure 16
Section through a wooden hull



Source: W.F.A. 1975

The North American Indians used tree bark on a simple, very light, wooden framework to construct canoes suitable for use in rivers with numerous rapids where it was essential to be able to carry the canoe round obstructions in the river. In Britain, small boats called coracles, made by sewing animal skins over a simple wooden framework were constructed in the past. Islanders of Tristan da Cunha in the south Atlantic use long boats made by sewing water-proofed canvas over a wooden framework. Tristan da Cunha does not have trees for boat building and it is also very isolated, making the importation of timber expensive. The very rough seas in the area, and, until recently, the lack of a protected harbour, required beach landing boats. It was, therefore, essential to have boats that as well as being extremely seaworthy, were also capable of launching and landing through large waves onto a beach.

Small boats built from timber planking do not have to be built on a framework, the planks can be joined together to form a structure strong enough to bear the stresses it is likely to be subjected to. This type of construction can be considered as a load-bearing stressed skin, more commonly used with some of the newer boat-building materials. The traditional 'Sesse' canoe of Lake Victoria, East Africa, is constructed from planking built onto a single central plank that is essentially a cut down dugout canoe, the planking is traditionally fastened together by sewing with natural fibres but strips of thin galvanized sheet steel and wire nails are often used today.

The past 100 or so years has seen the introduction of several new materials for boat construction. Timber is no longer used for the construction of large ships but is today one of several alternatives available to the designer of smaller boats. Each material has its own properties and tends to be used for particular types of construction, depending on specification. Two important considerations in drawing up the specifications for a boat and in selection of the construction material or materials are the cost and availability. Any boat-building material should possess certain properties: it should be strong; waterproof; long lasting; easily worked; resistant to attack by fungi, insects, salt water, oils, chemicals and fouling organisms; easily repairable; readily available and low in cost. Most materials possess only some of these properties, and a fisherman, boat-builder or naval architect must chose the one, or ones, that fulfil as many as possible of the points laid down in the design considerations. As choice is involved and each material has good and bad properties, differences of opinion as to which is the most suitable material to construct a boat for a particular purpose are bound to occur, fishermen and designers may have strong personal preferences. Fishermen tend to be conservative by nature, especially those from traditional fisheries that have changed little for many years. Introduction of new designs of fishing craft constructed in unfamiliar materials can meet with resistance from fishermen. Consideration should be given to introducing new designs constructed, as far as possible, from traditional materials with traditional methods, or building a boat based on a traditional design in a new material. Improvements to a traditional 'Sesse' canoe of Lake Victoria, East Africa, have been undertaken from both these viewpoints. Several designs constructed in wood are based on the traditional canoe form but use better constructional techniques. They utilise standard sizes of sawn timber, and a transom suitable for attaching an outboard motor is incorporated. The boat is more seaworthy and will carry a greater load than the traditional canoe. A later development was the construction of a glass re-inforced plastic (GRP) canoe based on the lines of the traditional type. Fishermen accepted the new boats and purchased them on a Government subsidy scheme from approved boat builders.

The best material is the one giving the boat owner the lowest yearly cost, expressed as:

$$\frac{\text{initial investment} + \text{interest} + \text{maintenance cost}}{\text{economic lifetime}}$$

For comparison, fishing ability must be considered identical, regardless of the construction material, as long as the same equipment and fishing gear are used. Exact projections of the economic life of a fishing boat are difficult to establish. The hull may still be sound after 10 years, but the boat itself may not still be considered

an economic fishing unit. Choice of a particular material for the hull will obviously affect the cost of the boat, but it should be remembered that this is not the major part of the total cost of a new boat.

Engine and equipment, fittings, boat yard overheads and profit margins must all be taken into calculations of the total cost. Gulbrandsen makes the point that the cost of material for the hull of a 12.6 m length overall (L.O.A.) boat designed for Lake Victoria contributed between 8 and 16% of the total price. Therefore, selection of a particular material may not greatly change the total price of a particular design of boat.

THE DEVELOPMENT OF MODERN FISHING BOATS

This century has seen the introduction of radical changes to the design, construction and operation of fishing boats in the developed fisheries of the world. Engines for propulsion and powering ancillary equipment, such as winches and power blocks for gear handling, have allowed the introduction of new fishing methods and increased the efficiency of existing gear. In the past, the number and physical strength of the crew, even with the use of hand-powered capstans and blocks and tackle, limited the types and size of gear that could be used. Sailing trawlers operated from the West of England before the introduction of steam engines and winches, but the net was a small one by today's standards.

Developments in the smaller sizes of fishing boats have concentrated on the mechanisation of gear handling and the fitting of insulated fish-holds to allow for the storage of iced fish. Space limitations on the smaller boats restrict the fitting of processing and handling equipment. The operating range of small boats is also restricted by the quantity of fuel that can be carried. Fishing trips are normally of only several days' duration, and simple storage facilities for holding the catch are sufficient.

Larger ships by virtue of their greater range and the space available can be developed to fulfil a range of functions. In most cases the ship is designed for one type of catching technique and the handling, preservation and, possibly, the processing of the catch. In some instances, the boat may be capable of fishing several types of gear (combination fishing vessels). Table 1 lists some of the basic types of larger fishing vessels.

Several nations operate very large factory ships in distant waters. A fleet of smaller catcher boats may supply the factory mother ship with fish for processing, or the mother ship may catch its own fish. Fish may be frozen whole, filleted and frozen, canned, or whole fish or fish offal reduced to fish meal. The range of processes

Table 1

Fishing boat types

Principal fishing method Boat type	Handling	Preparation	Processing	Preservation	By-products
Liner	On deck	Gutting		Ice	Liver oil
Long liner	On deck	Gutting		Ice	Liver oil
Tuna long line	On deck	Gutting, gilling		Freezing	
Tuna pole line	On deck			Brine freezing	
Troller	On deck	Gutting		Ice, RSW*	
Seiner	On deck	Gutting		Ice	
Tuna purse seiner	On deck			Brine freezing	
Drifter	On deck			Ice, CSW†, RSW*	
Trawler near water	On deck	Gutting		Ice in box	Liver oil
Trawler distant water					
a) side	On deck	Gutting		Bulk in ice	Liver oil
b) stern	Below deck	Gutting		Bulk in ice, freezing	Liver oil
Factory vessel	Below deck	Filleting	Canning	Freezing	Fish body & liver, oil, fish meal

*RSW Refrigerated sea water
†CSW Chilled sea water

carried out depends on the species available and the market demand for that species. Fishmeal is prepared from trash fish, fish offal or, in times of a high catching rate, with the fish surplus to the capacity of the processing equipment. Many of the world's traditional fishing nations are exploiting their inshore, near and middle distance fisheries very intensively and additional supplies of fish must be sought from distant waters.

The demand for additional supplies of fish and fish products has led to the development of vessels with sufficient range, processing and storage facilities to exploit distant waters economically. It should be noted that extraction of liver oils and the reduction of offal and trash fish to fishmeal help to improve the economics of operating distant-water vessels. Such vessels may only be economically worthwhile if every part of every fish can be used.

The design, construction and operation of all large fishing vessels demands specialist knowledge, skill and experience, and is beyond the scope of this report. Junior fisheries workers in developing countries would not be expected to fully understand such topics and the foregoing was intended to serve as an introduction to the subject of larger vessels and to illustrate the range and types in use. Mechanisation and modernisation of small fishing boats may well be a task for the fisheries worker in the field who may have to advise fishermen on methods of improving existing boats, or inform them of departmental schemes for improving existing boats or introducing new ones. Some departments operate loan schemes or give grants to enable fishermen to purchase new boats or fit engines to existing boats as mentioned in Chapter 1.

Small boats can be improved in several ways and the situation in each fishery will determine the types of improvement likely to prove beneficial. Current practice in the developed fishing nations may not necessarily be applicable in a developing fishery and any new methods or ideas should be tested under local conditions before being recommended to the fishing community.

Many fishing communities using small open boats have increased the range of their operations and are no longer dependent on sails or paddles since the introduction of outboard engines. An outboard engine requires only a very simple modification to a small boat to enable it to be fitted securely. It is easily removable for repairs and safe keeping, easy to operate and fairly simple to maintain. In its normal position clamped onto the transom (Figure 17), it occupies almost no space within the hull, and it is unlikely to contaminate the bilges with oil or petrol drippings. An outboard engine can be positioned in several places, depending on the construction of the boat, and the operating methods. A simple bracket built onto the gunwhale allows the engine to be mounted over the side, a system used by some canoe fishermen in West Africa who have to launch and land boats through surf (Figure 18). The engine may be removed, covered and securely stowed inboard before going through the surf.

Engines can be mounted on wells fitted through the bottom of the boat (Figure 19) the positioning of the well varies in different types. In skiffs used in North America, the outboard well is placed forward, allowing a full width net roller to be fitted across the transom for setting and hauling nets.

Most outboard engines available today have been designed for a small, light-weight, high speed boat, not for heavy, low speed work boats. However, their specification is often suitable for use with many of the relatively narrow traditional canoes found in developing fisheries. The 'power pole' is a type of outboard engine used in the Far East, particularly Thailand (Figure 20). A stationary engine is mounted on a tilting and swiveling platform in the stern, a long pole with a propeller on the end of it provides the drive linkage. The unit is suitable for use in calm and shallow waters, facilitates manoeuvrability and, as small mass-produced petrol engines are used, it is cheap to purchase and simple to maintain. Large diesel engines have been converted to power poles on heavy barges on the inland waterways of Thailand.

Almost all outboard engines require petrol as a fuel, the majority of these are two-stroke engines, as compared with most inboard engines which are diesels. Consider-

Figure 17
Transom mounted outboard engine

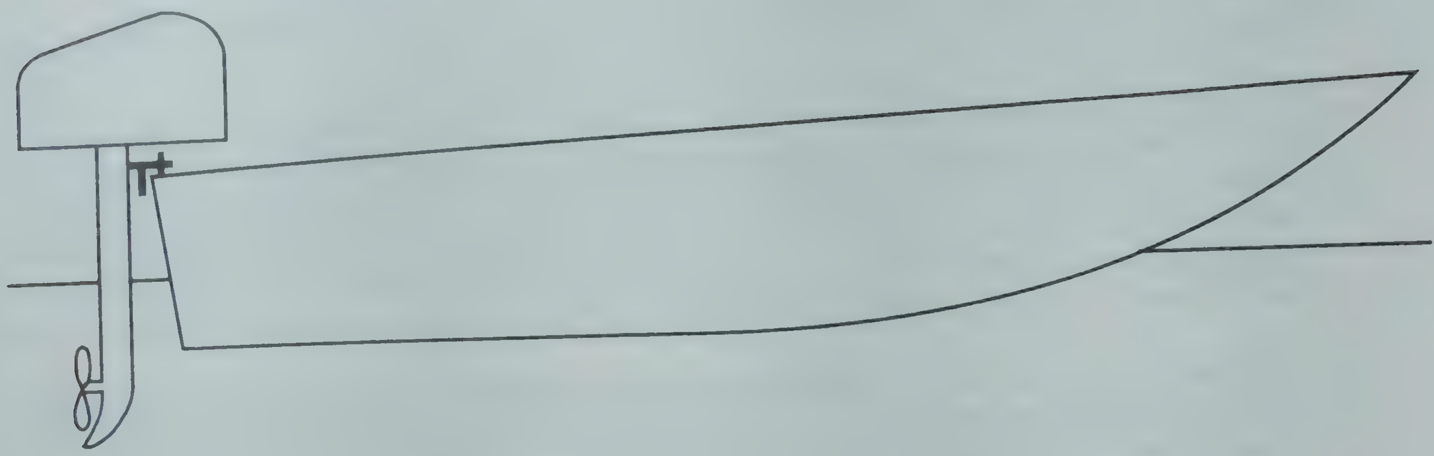


Figure 18
Side mounted outboard engine

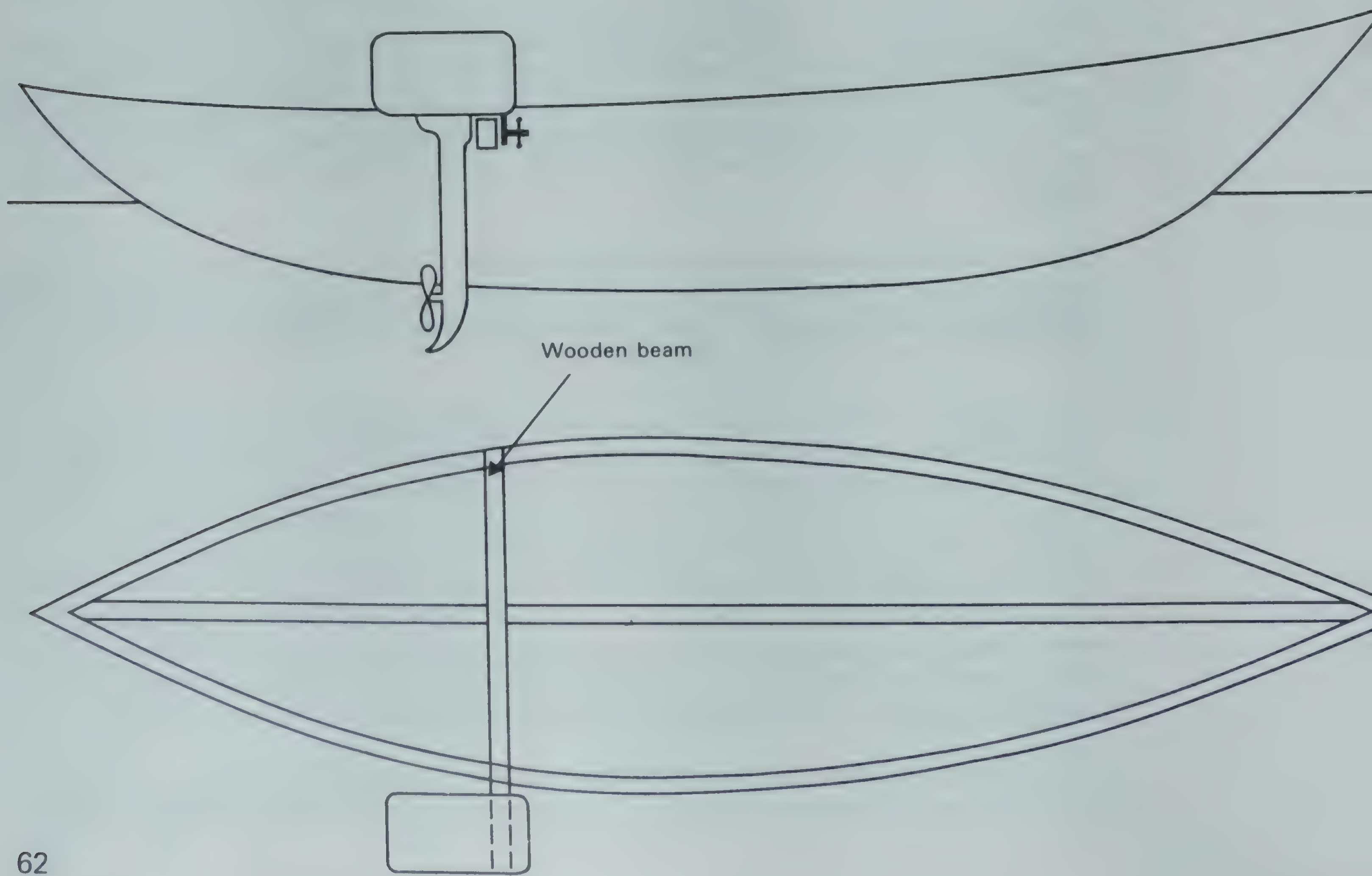
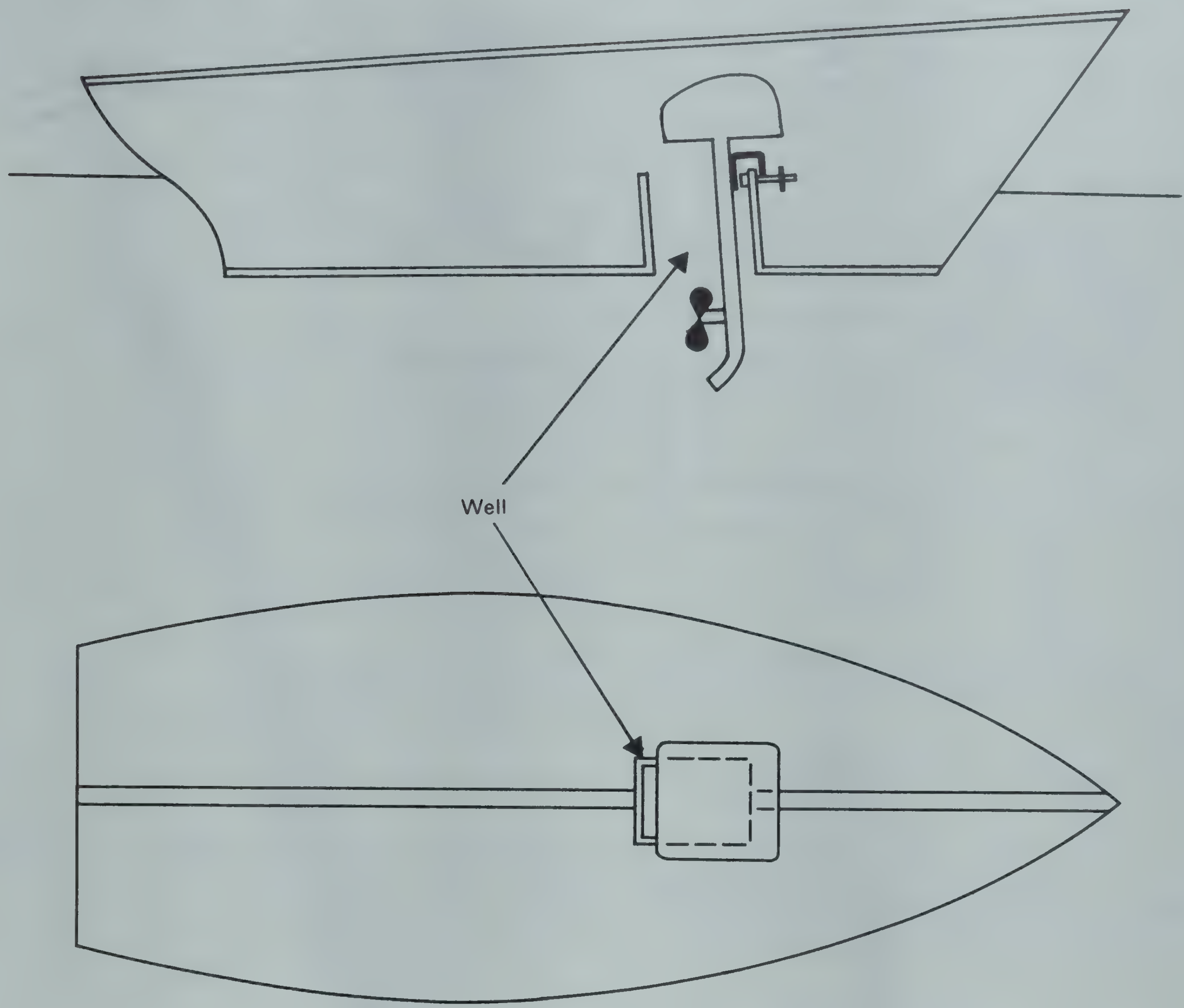


Figure 19
Well mounted outboard engine



able discussion has taken place on the relative advantages and disadvantages of each system. In any project for fitting engines to boats the advantages and disadvantages of each system should be considered. No one system should be accepted regardless of circumstances. The following list gives the advantages and disadvantages of outboard over inboard engines:

1 The boat will be considerably lighter and can therefore carry more fish and gear.

2 There is more space for fishing operations.

3 The boat construction is simplified, engine bed, shaft log and rudder installation are not required.

4 Lower installation costs.

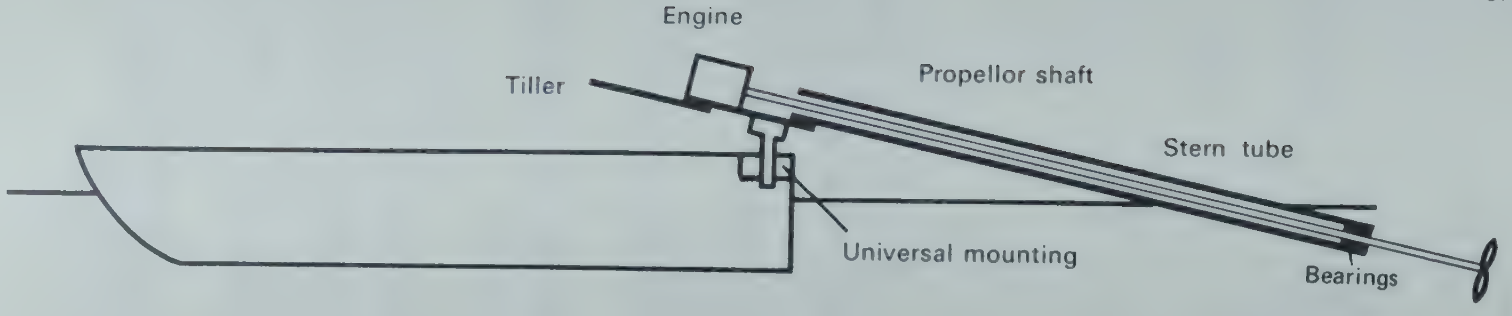
5 The cost of the engine is only a fraction of the cost of a diesel engine.

6 As the combination of engine and stern gear is 'factory made', there is less possibility of stern gear troubles.

7 The boat does not have to be beached when repair work is needed on the engine, stern gear or rudder.

8 The fishing time lost for repairs, as in the case of inboard engines, can be reduced to almost nothing by replacing the outboard by another in a matter of minutes.

Figure 20a
Power pole (long tail engine)



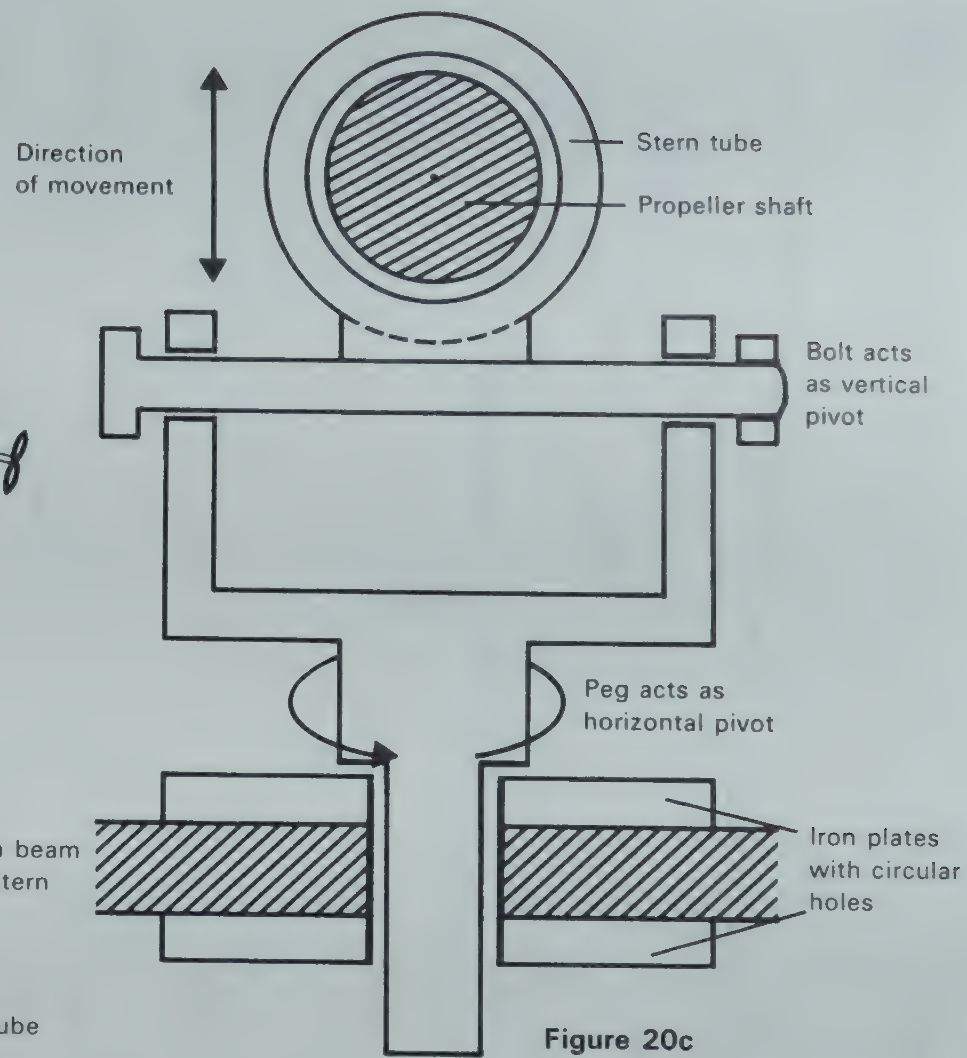


Figure 20c
Detail of universal mounting

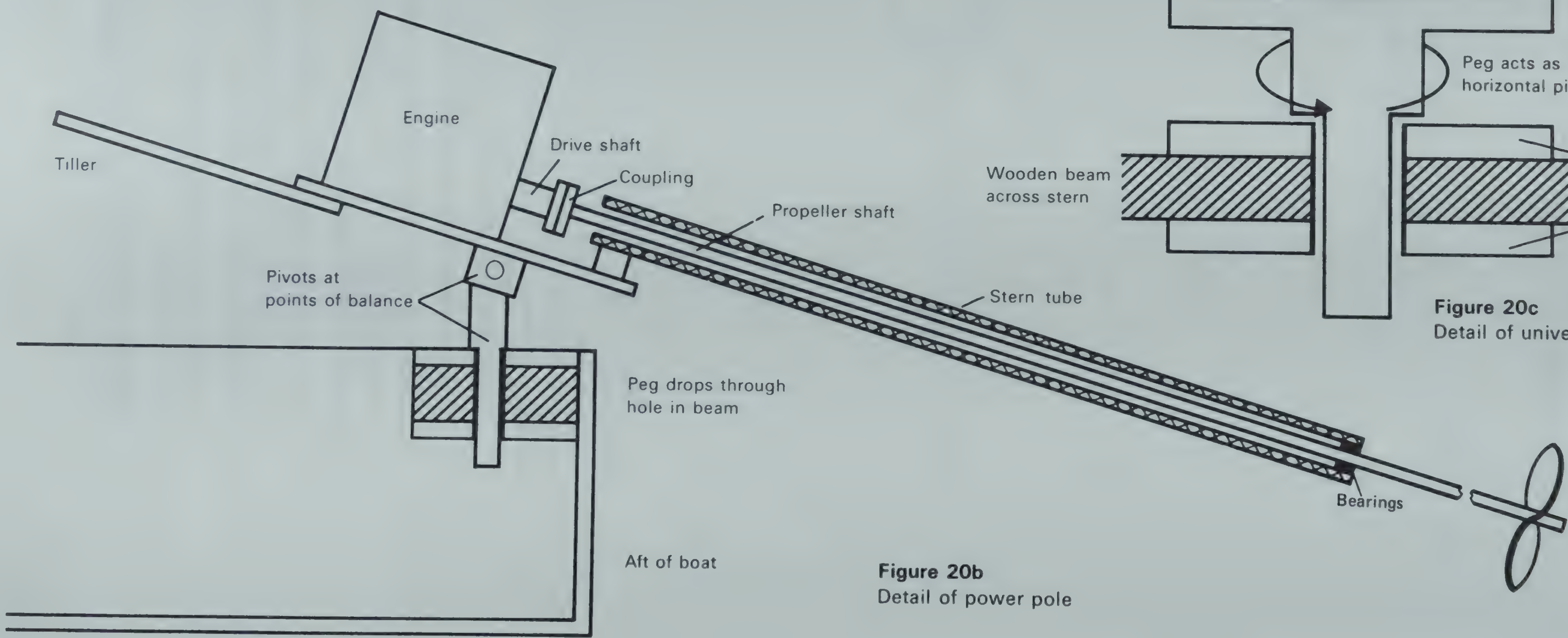


Figure 20b
Detail of power pole

9 The propeller acts as a rudder, which affords the boat better manoeuvrability when going through surf. With an inboard engine the rudder is practically useless in surf when the water flow is of the same direction and speed as that of the boat.

10 With an outboard installation, the possibilities of the craft sinking are greatly reduced because of the reduced weight of the hull and engine. The engine could also be jettisoned in an emergency. This eliminates the need for having the boat decked from a safety point of view.

11 The water flow to the propeller is more even than with an inboard installation.

12 Some outboard engines are fitted with electric generators that can be used to charge batteries for self starters and light-duty electrical equipment.

Disadvantages of outboard engines against inboard engines are that:

1 Several types of outboard engine are run with a high compression ratio, and therefore require a high-octane fuel.

2 The price of fuel is sometimes very high.

3 The specific fuel consumption is twice as high as that of a diesel engine or inboard engine.

4 The life of the engine is short.

5 The propeller selection is limited.

6 A power take off is not available on most engines (a small pot or line hauler that is operated from a power take off attachment to a 4 h.p. outboard engine is manufactured commercially in the UK).

MATERIALS AND METHODS OF CONSTRUCTION FOR FISHING CRAFT

Fishing boats today are constructed in a range of materials, in some cases two or more materials may be used, e.g. many wooden hulled boats are fitted with aluminium deck houses and whalebacks. Originally only naturally available materials were used but today several new materials have been developed that are suitable for the construction of boats.

Here we review the main materials used in boat construction, outlining their basic properties, the ways in which they are used and giving an indication of the cost relative to the other materials. Table 2 illustrates the basic properties of materials commonly used in boat construction.

Table 2

Basic properties of boat building materials

Material	Material cost	Ease of construction	Resistance to damage	Ease of maintenance and repair
Wood	High, varies with local supply	Demands skilled labour	Burns, strong and durable but damage tends not to be localised.	Requires regular maintenance and protection, repairs demand skilled labour. Mainly local material.
Glass reinforced plastic	High, unless volume production	Skilled labour for mould, semi-skilled labour for production	Burns, susceptible to impact damage and abrasion.	Little maintenance required, repairs simple providing fresh resins and/or good storage facilities available. Semi-skilled labour adequate.
Steel	Generally low, if technology available	Skilled labour and some specialist machinery	Does not burn, durable, but liable to corrosion if not protected.	Requires regular maintenance. Repairs demand skilled labour.
Ferro-cement	Generally low, uses commonly available materials	Skilled supervision of semi- or unskilled labour	Durable, damage localised.	Little maintenance required. Repairs simple and cheap with semi-skilled labour.

Wood

Although there are numerous timbers available, only relatively few are suitable for boat-building. Timber for boat-building must be durable, especially with regard to resistance to physical knocks and attack by insects and fungi. It must be strong, fairly easy to work and capable of being bent into curved shapes. A timber, such as Burma teak, which fulfils most of these requirements is in great demand and consequently commands a high price on the world market.

The suitability of a timber for boat building is a combination of the basic properties of the timber itself (intrinsic) and the method of cutting and preparation before use (extrinsic). Only timber of straight grain almost free from knots is suitable for planking. The way in which the trunk is cut into planks can affect its properties, timber for planking is best sawn tangentially from a trunk and not radially. Although radially cut timber will not curve (cup) as it absorbs water it is more likely to crack. Tangentially cut planking should be laid with the annual rings curving inwards as any cupping that results from absorbtion of water will not lift the edges of the planks (Figure 21). All freshly cut timber must be properly seasoned before use to bring the moisture content to the required level, normally between 10 and 12% for boat building. Timber that is too wet will shrink later and many of the joints above the water line will open, if it is too dry it will absorb water and expand and may push the planking off the frames. If correctly seasoned, expansion will just be sufficient to securely close all the joints without weakening the structure. Curved timber (grown crooks) can be used to form frames instead of making them from straight grained pieces (see Figure 22).

Wooden construction can be divided into two main categories, one in which pieces of timber are used and the second in which thin laminated sheets of wood (plywood) are used. When a boat is referred to as being constructed of plywood this normally refers only to the outer layer of the hull. The frames and keel pieces are fabricated from normal timber. Plywood construction will be dealt with later.

There are a whole range of ways of constructing a wooden hull utilising different techniques. Few fisheries workers need to have a detailed knowledge of the various types and methods of construction. However, they should be aware of the salient features of each major method of construction and have an understanding of how boats are built.

Clinker or lap-strake construction

The hull is formed from thin planking in which the edges are overlapped and fastened with riveted or bent (clenched) nails (Figure 23). Very often clinker boats are built over a mould. The keel, stem and transom are fixed on the mould and the planking is built up over the mould. Light, steam bent frames are fitted into the hull of smaller boats after the boat has been removed from the mould. Clinker built boats are strong, light and suitable for operation in rough water. It is a difficult method of construction as the joints between planks must be lined-off (faired) accurately to ensure a tight fit. Caulking is not used to seal joints between the planking. As the planks are overlapped and fastened to each other, repairs are difficult. Wide, thin planks are necessary for the construction and this can cause problems when building large hulls as very wide planking is not easily obtainable. If relatively narrow planking has to be used, the labour required is increased and a greater number of fastenings will also be necessary. A hull built from narrow planking will be heavier than one built from wide planking because of the more numerous overlaps and fastenings. Planking must run from stem to stern and scarf joints (Figure 24) must be used to join the pieces forming a plank. It is preferable to use planks cut from a single board so avoiding joints, although this is only practical for small hulls.

Carvel construction

A form of construction used for round bilge boats, particularly those over 7.6 m (25 ft) long.

Figure 21a
Cutting planking

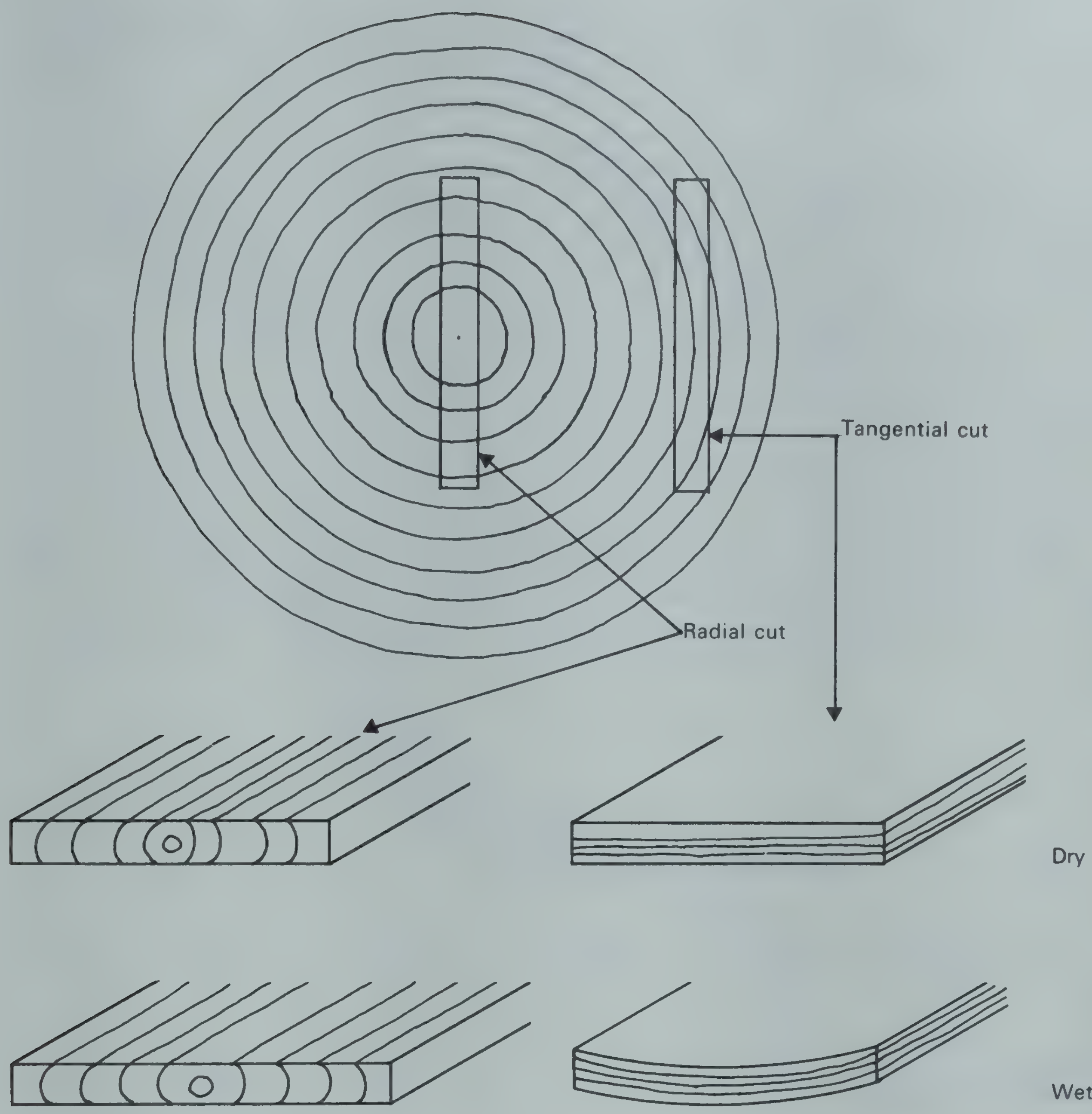


Figure 21b
Right and wrong way to fasten planking to frames

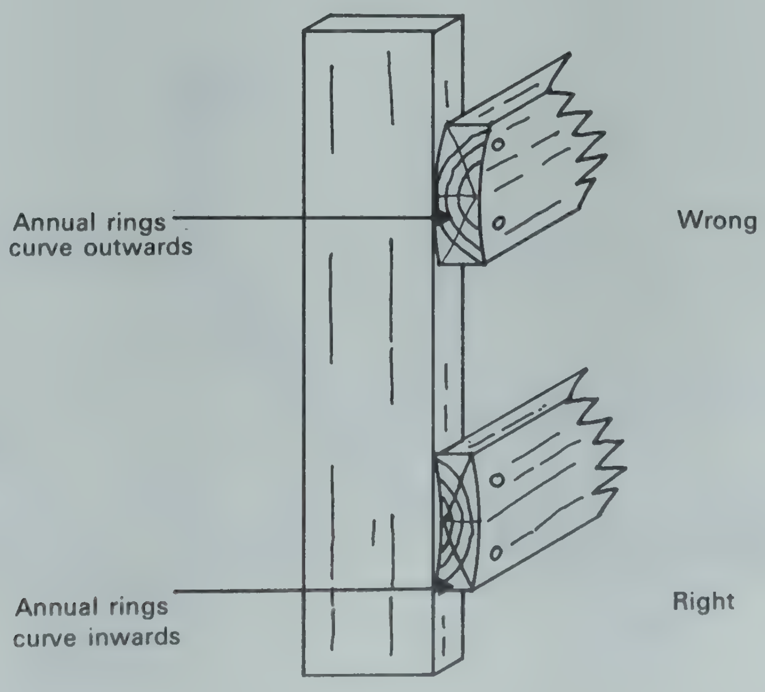
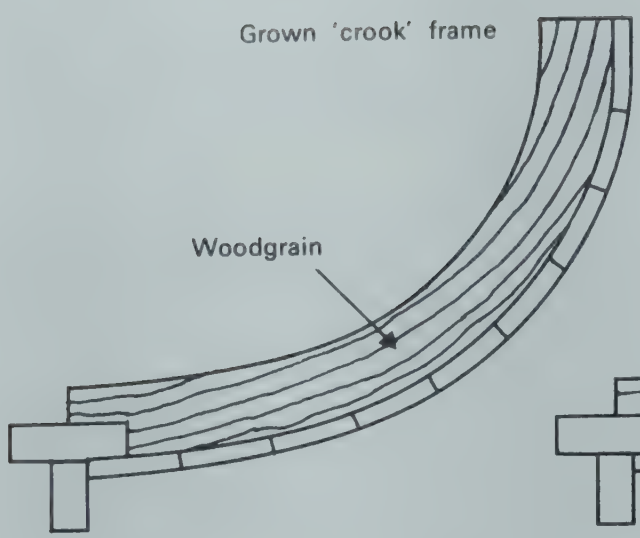
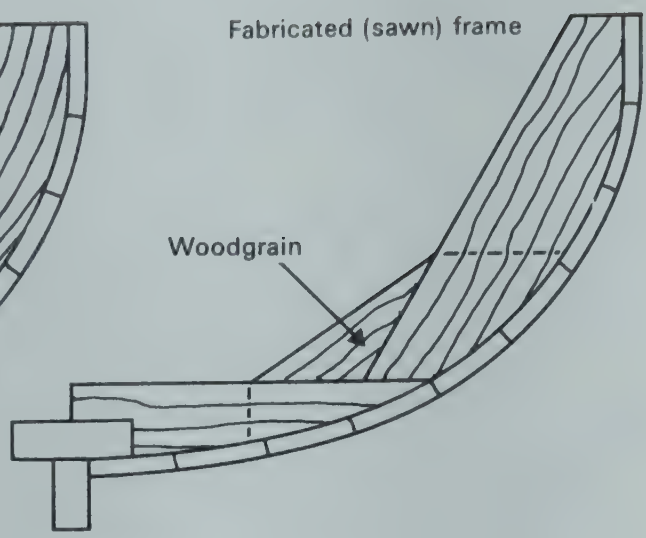


Figure 22
Frames





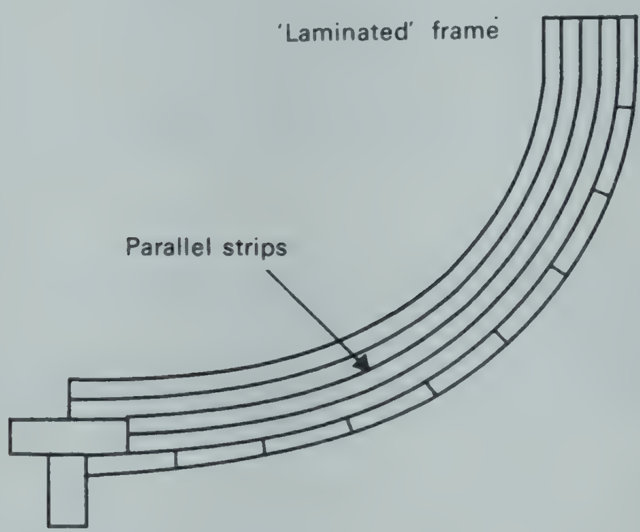
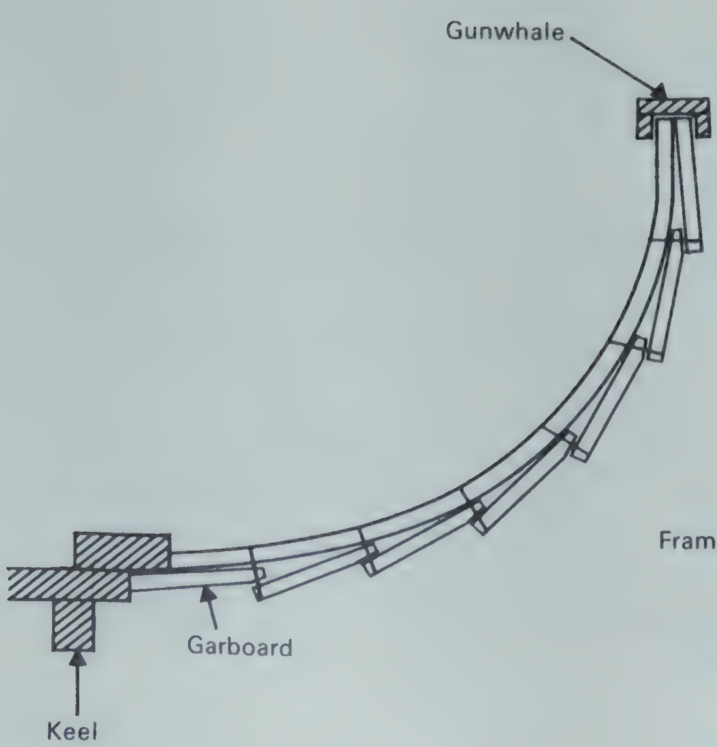
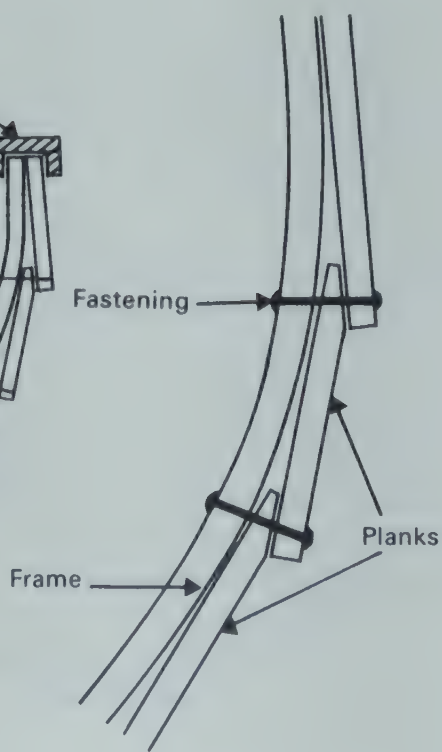


Figure 23
Clinker-plank fastening





A basic framework is constructed on the keel and the planks are attached to this (Figure 25). The keel and frame form the main structural members of the hull, with the planking being essentially a waterproof outer membrane. In practice the planking contributes significantly to the strength of the hull. Normally planking is fixed longitudinally, (fore and aft) in a single layer. Planks are fixed directly to the frame with galvanised iron nails or copper, brass or bronze (non-ferrous) fastenings, planks may also be fastened one to another.

Several alternative arrangements for attaching the planking to the hull are used. Longitudinal, or fore and aft planking is the most frequently seen arrangement for carvel built hulls. Planking may also be laid diagonally where specified for certain specialised types of hull, for example in high-speed power boats where a wide flared bow is used to reduce the shipping of water and spray. Double skins of planking are also sometimes specified (Figure 26), the planking skins may be laid counter-diagonally, or with the inner skin laid diagonally and the outer skin laid longitudinally. A thin layer of cloth or similar material is very often glued into position between the two skins. With double skin construction, care must be taken rounding the bilge, to ensure that the inner and outer layers are carefully fitted together to prevent splitting. It may be necessary to hollow out the inner face of the outer planks and round off the outer face of the inner planks. Occasionally only narrow planking is available and this can be used for strip planking (Figure 27). The edges of the timber may be shaped so that they fit together closely without the need for caulking. Narrow or strip planks may be fastened one to another and also to the frames. Various methods of planking are illustrated in Figure 28.

Figure 24
Scarf joint

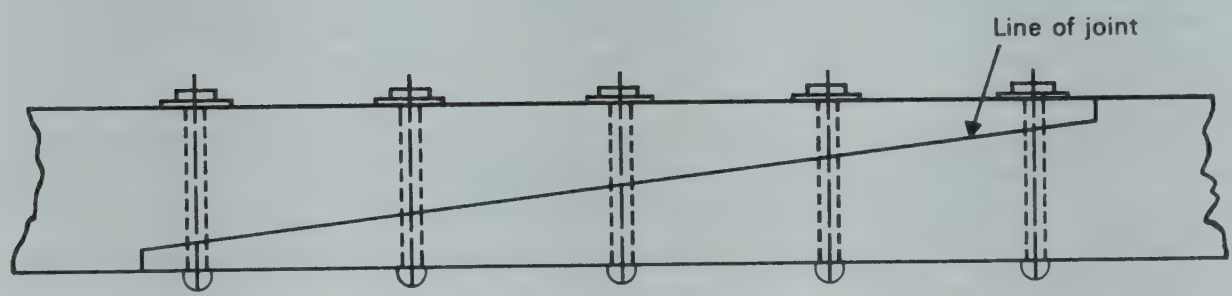


Figure 25
Carvel construction

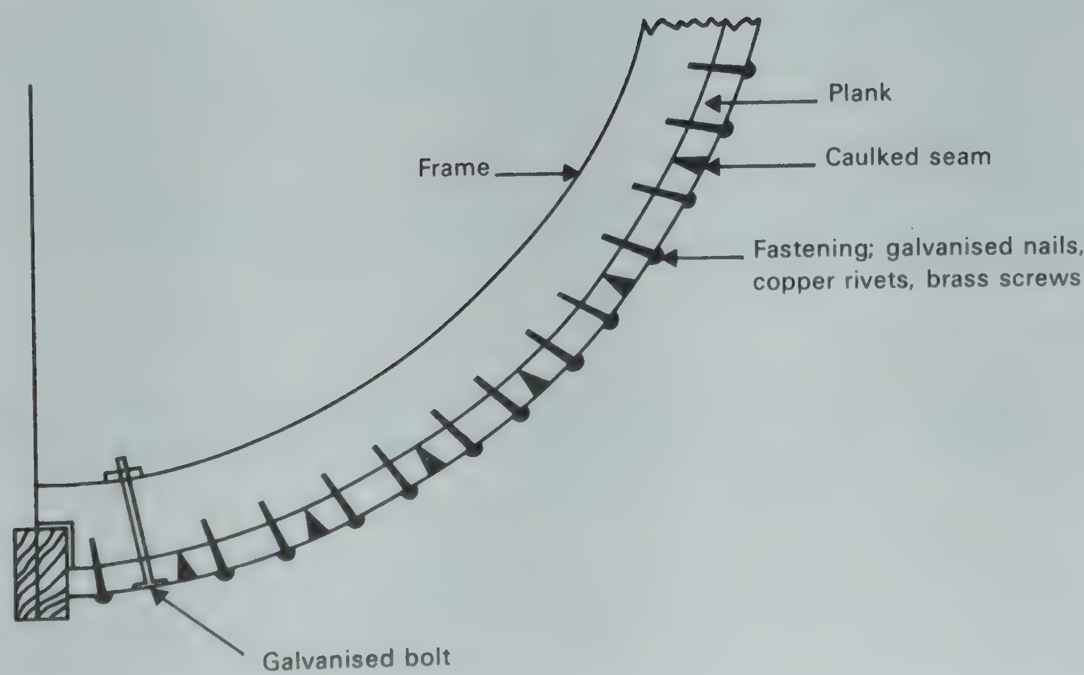


Figure 26
Double planking

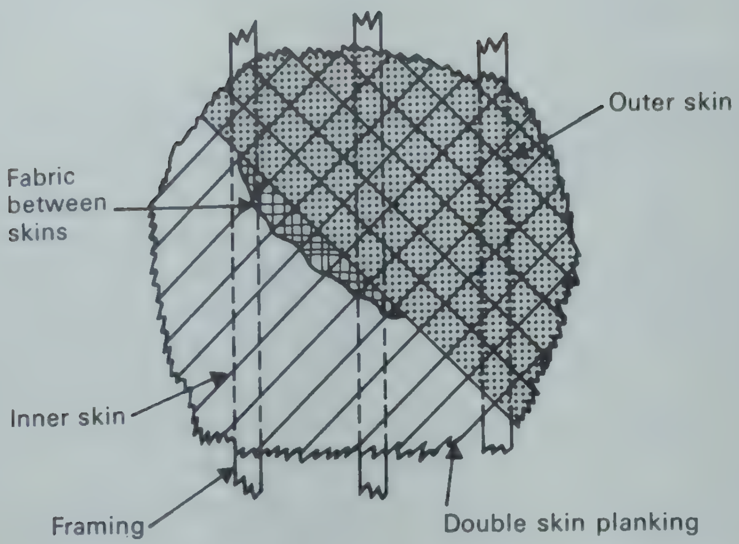
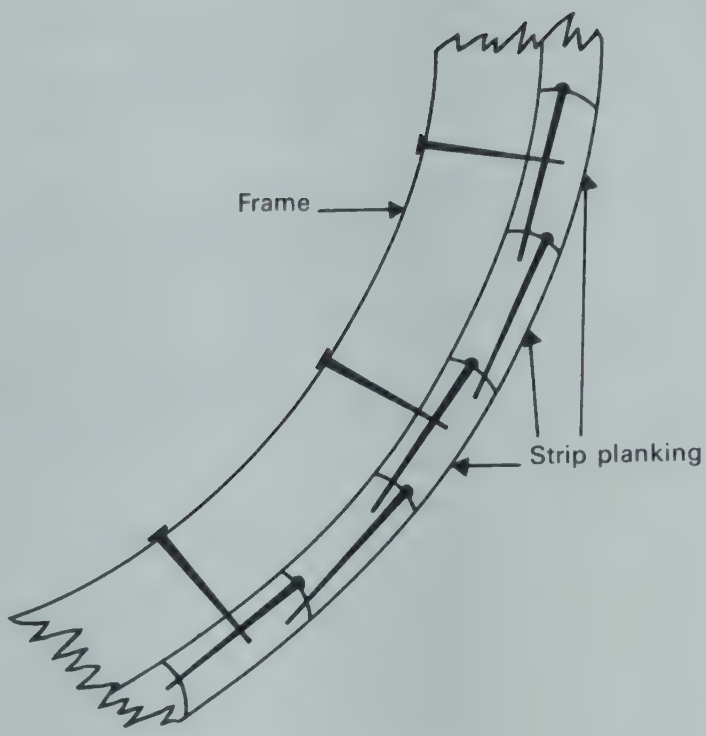


Figure 27
Strip planking



Source: W.F.A. 1975

V-section construction

A form of construction where the hull, in section, is formed from a number of flat faces joined together at an angle. In its basic form a boat hull could be formed in a simple V. In practice, the hull is made of several flat sections.

As with carvel built boats, a 'skeleton' of keel and frames is constructed and the planking is fastened to this. Planking may all be laid longitudinally as is the practice with multi-chine hulls (Figure 29). The bottom planking in a single chine boat (Figure 30) may also be laid across the line of the hull, normally in a herring-bone arrangement (Figure 31).

Many designs of flat bottomed boats suitable for operation in shallow water are cross-planked on the bottom; protective keel and bilge (chine) runners are fitted later. (Figure 32).

Caulking

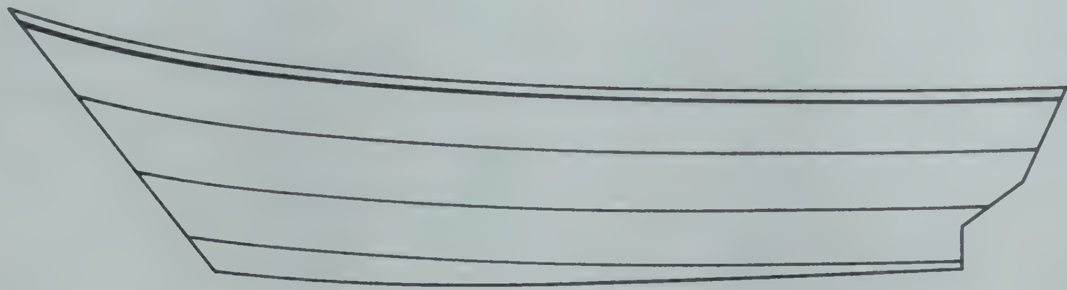
In all forms of wooden boat construction where the planking is butt joined, i.e. carvel, the joint is sealed by caulking (see Figure 33). A loosely twisted strand of cotton or oakum is forced into the joint with a special thin bladed tool (caulking iron). The planking will swell slightly when the boat is put in the water and the caulking absorbs the expansion and forms a waterproof joint. Very often the joint between planks is filled with putty or pitch after the caulking has been driven in. The edges of the planking may be chamfered slightly to allow the caulking cotton to be driven in securely.

Ventilation and spoilage

Timber is liable to spoilage from a variety of causes and as timber is used in almost all boats, regardless of the main materials of construction, certain precautions must be taken to obtain a reasonable working life.

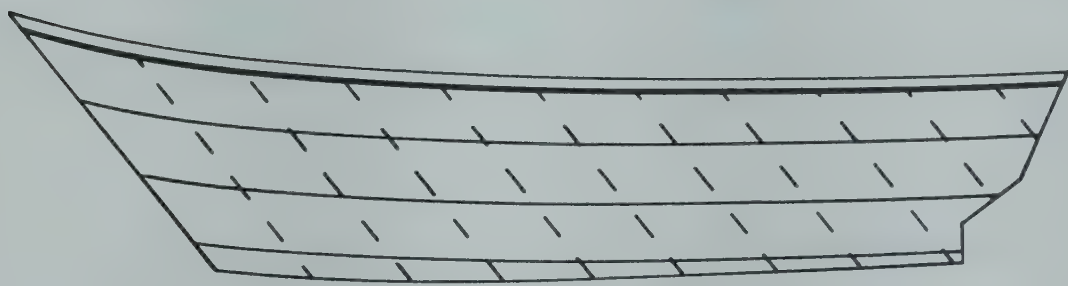
Some marine organisms can bore into timber and over a period of time seriously weaken the structure. If you are operating in an area where marine borers are a problem it may be necessary to sheath the hull with copper to prevent entry of the organisms.

Figure 28
Planking methods for round bilge hulls



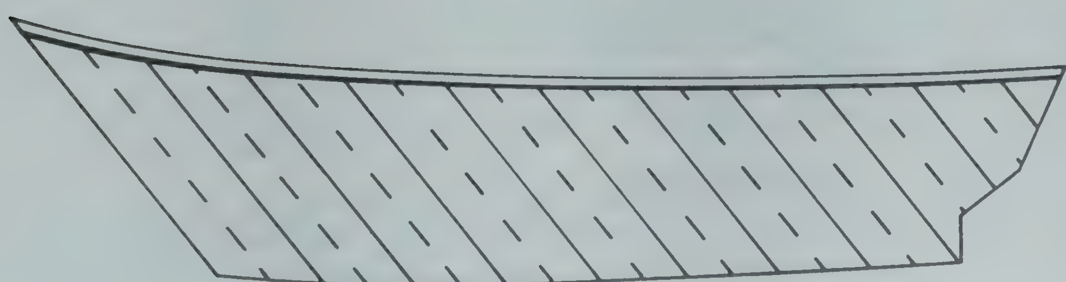
Single skin — longitudinally planked

Single skin — diagonally planked



Double skin — inner diagonal, outer longitudinal

Double skin — counter (double) diagonal



Double skin — diagonal, both in same direction

Figure 29
Multi-chine

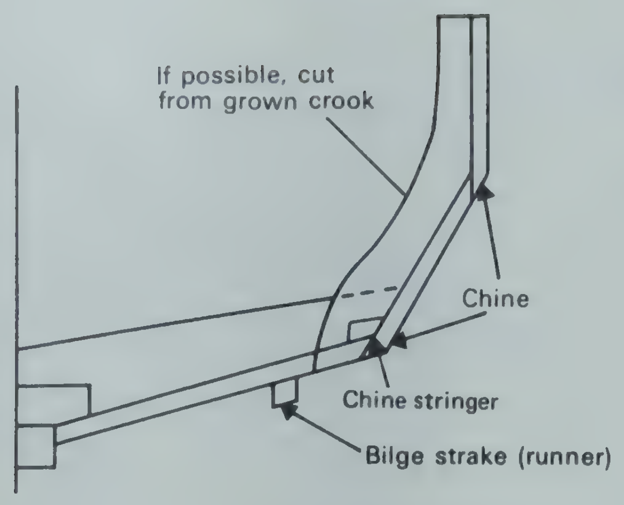


Figure 30
Single chine

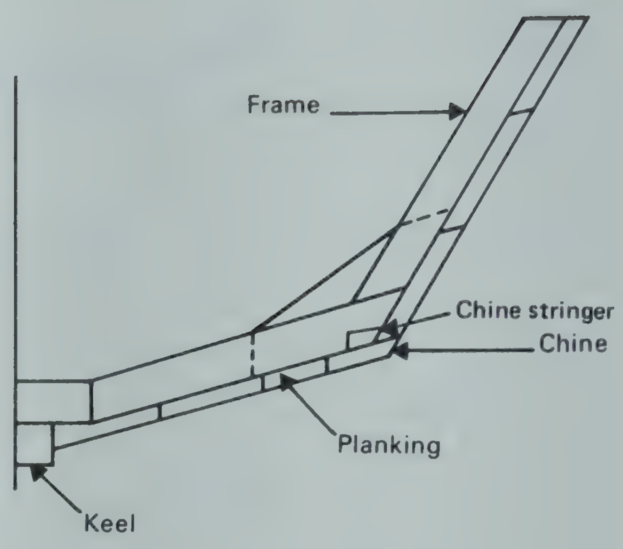
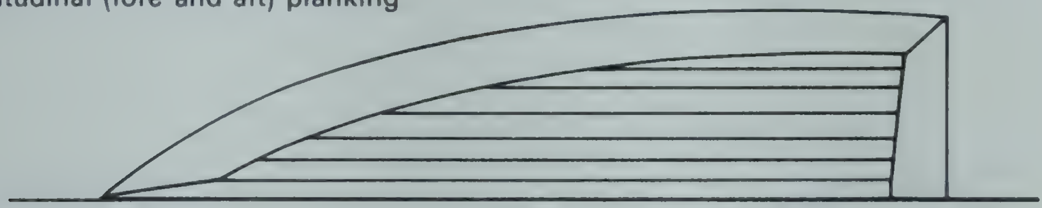


Figure 31
Types of planking

Longitudinal (fore and aft) planking



Herring bone planking

Figure 32
Cross-planking

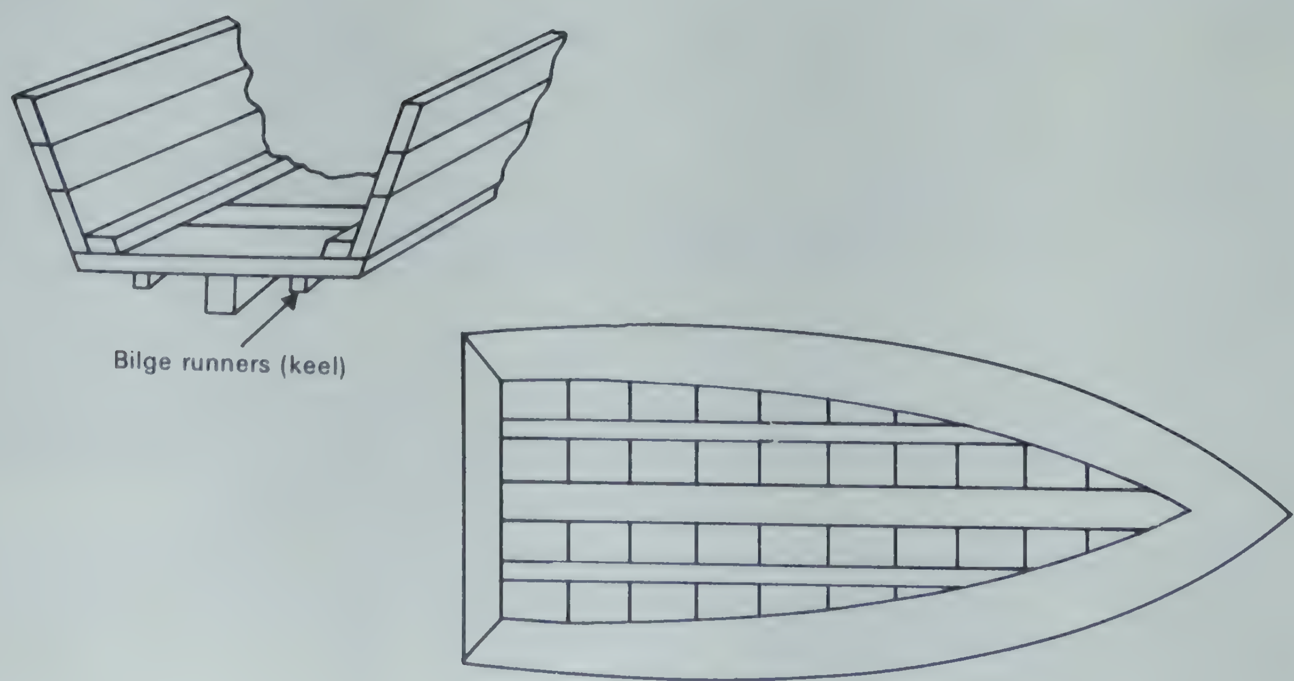
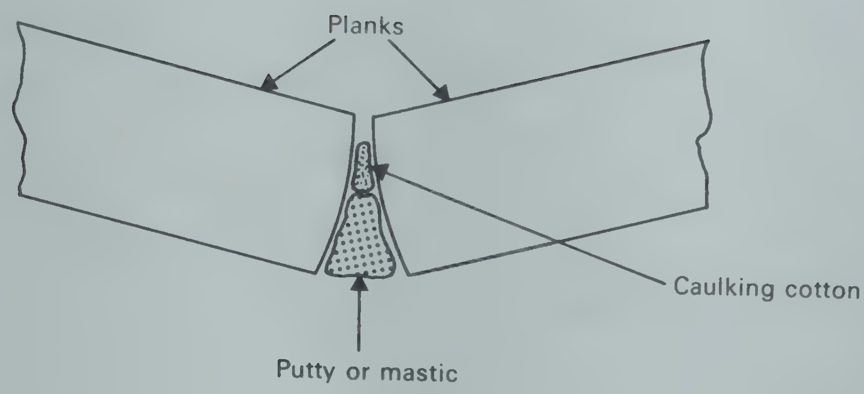
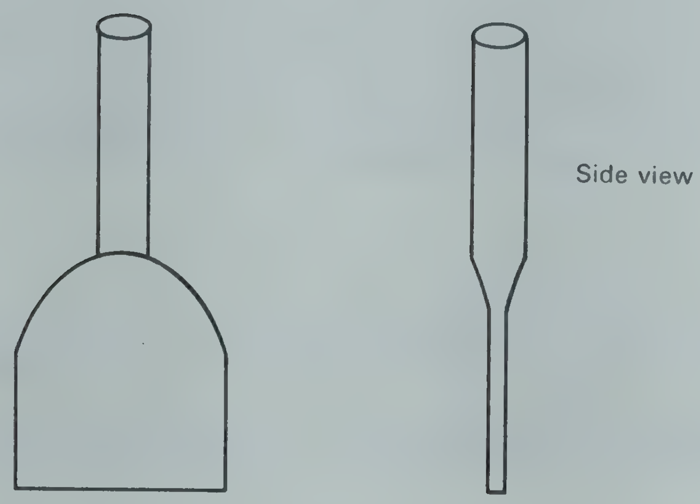


Figure 33
Caulking





Caulking iron - various shapes and sizes are used

A number of fungi attack timber and can completely destroy its structure if not checked, this is normally referred to as 'rot' and can occur in several ways. Permanently wet or dry timber is not liable to attack, but damp timber, particularly in airless conditions is vulnerable. Ventilation of a boat hull is therefore of importance, even where timber is only used for the fishroom linings and other internal structures. In a wooden boat, fishroom insulation should not be built against the hull timbers, battens should be fixed across the frames to carry the insulation and allow the circulation of air on the inside of the planking and around the frames.

Resistance to rot is an important consideration in selecting a suitable timber to build boats as the intrinsic resistance varies from timber to timber, Burma teak is an example of a timber with good resistance. Anti-fungal chemicals may be applied to a timber to increase its resistance, although it may be necessary to take additional precautions to reduce the leaching of the chemicals from the timber by the water. In Uganda several experimental boats were built from a timber that was pressure impregnated with an anti-fungal compound. The timber selected was suitable for boat building except for the fact that it had poor resistance to fungal attack, it was also much cheaper than the normal 'good' boat building timbers which were also valued by the furniture and construction industries in the country and overseas.

Excessive drying, especially in direct tropical sunlight may cause timber to shrink and split, which weakens it and may allow the entry of water. Topside timber, particularly decking should be regularly washed down to stop it drying out.

Plywood

Plywood is formed by bonding together thin sheets of wood. An odd number of layers is always used so that in the finished material the grain on both faces runs in

the same direction. The grain in alternate layers is always laid at right angles, this ensures that the finished material does not warp and that expansion or contraction of the sheet along its length and across the width is very slight. Thin material is normally built up of 3 skins (3-ply), but 5, 7, or more skins may be used in thicker material. One or both of the outer surfaces may be of durable or decorative timber. For all boat-building purposes a waterproof adhesive must be used to bond the plywood. If an adhesive that is not fully waterproof is used the layers are likely to fall apart (delaminate). Very often an inexpensive timber is used for the inner layer or layers and this may be liable to rot. Plywood should always be painted or varnished, particular care being taken to ensure that the edges are sealed to prevent the entry of water. The various skins of wood used can be treated with preservatives before they are bonded together. In the UK several 'British Standards' have been published that detail recommended standards for the construction and protection of plywoods for various purposes. If plywood is to be used in large sheets it can only be bent in one plane. A sheet of paper has similar properties; you will find that it can only be bent in one direction without creasing, which can be compared to the splitting or cracking of plywood if it is attempted to bend it in two planes. In general, plywood is only used for small and medium-sized V-section or flat-bottomed boats. The life of a plywood hull should be similar to that of any other wooden boat, provided that it is properly constructed and well maintained throughout its working life.

Glass reinforced plastic

Glass reinforced plastic (G.R.P.), or fibreglass, is a material that has been used for boat-building for only the last 30 years or so. Originally it was first used for very small boats such as dinghies but more recently it has been used for larger and larger boats. In the last few years small ships of up to 40 m L.O.A. have been built.

G.R.P. has, like all other boat-building materials, both good and bad properties. It is relatively light in weight compared with other materials, extremely durable and requires almost no maintenance. It is strong, has reasonable impact resistance and using the normal methods of construction can be formed into complex shapes. Repairs are simple and rapid. G.R.P. consists of a matrix of a synthetic resin reinforced with fibres of glass. In some ways it can be considered analagous to concrete reinforced with steel rods. The resin is hard and durable and the glass fibre reinforcing contributes strength and flexibility to large areas. Almost all G.R.P. boats are built from a mould as the resin is applied in a liquid state and must be supported until it has hardened (cured). A mould is made the exact size and shape of the hull. A releasing agent (wax polish) is applied to the surface of the mould to prevent the resin sticking. A gel coat, often containing a pigment, is first applied to give an attractive and built-in finish to the hull. Onto this a mixture of resin and glass fibre is built up. The glass fibre is available in several forms and selection depends upon which part of the hull it is to be used for. Resin comes as a liquid, to which a hardening agent is added just before use. Hardening (curing) should take place within 20—30 minutes of mixing. It is important that curing takes place at the recommended rate, this ensures that bonding of the material is complete and that the required physical properties are developed. It is very often necessary to control the temperature and humidity of the boat building area to give correct curing times. With large hulls, the G.R.P. is often brought up to the required thickness by the application of several layers (laminations), allowing each layer to cure before the next one is applied. The rate and conditions under which curing takes place must be correct if de-lamination problems are not to occur later. In tropical climates, it may be essential to build G.R.P. boats in air-conditioned sheds to obtain the correct curing rates.

One very important cost consideration with any G.R.P. boat is the expense involved in building the mould. In normal commercial practice G.R.P. boats are only competitive in price with other materials if a series of hulls are to be built from the same mould. The cost of the mould can then be written off over the production run.

G.R.P. is relatively maintenance free and does not require painting above the waterline, anti-fouling preparations are normally applied to the under-water parts.

For small boats the light weight of a G.R.P. hull can be an advantage, especially for high speed planing designs. However, for larger displacement hulls, the light weight may not confer any advantage as ballast may have to be carried to improve the sea keeping qualities. Ballast can be added in the place and quantities necessary to give the draft and trim required. With an intrinsically heavier hull, the amount of ballast that can be added without seriously affecting the carrying capacity is limited. Weight should be kept to a minimum on the upper parts of a boat and light-weight (e.g. G.R.P.) deck houses are often fitted to hulls constructed of other heavier materials.

Steel

Steel is normally restricted to the larger sizes of boats and ships from about 12 m (40 ft) upwards. Specialised equipment is necessary to cut the steel plates and for welding or riveting the pieces together. Shaping steel plates is a difficult and skilled job beyond the scope and facilities of many small boatyards. A steel hull is strong and durable and has a long life with proper maintenance. It is also not attacked by marine boring organisms which are a serious problem with wooden hulls. Rust can be a serious problem with steel hulls if they are not adequately maintained.

Aluminium

Aluminium or aluminium alloys are used for boat building in a similar way to steel, but they have the advantage of being much lighter than steel and not rusting. For many applications aluminium does not require painting above the waterline and the bare metal surface gives an attractive appearance.

Specialised equipment is required to weld aluminium plates together. Small hulls can be riveted.

Ferro-cement

Ferro-cement is a boat building material that has only been used for commercial fishing craft in the past decade. In its current form it was originally developed by an Italian, Nervi, in the 1940s. Prior to this, reinforced concrete ships and barges had been built utilising the normal wire rod reinforcing and concrete formed from sand, ballast (small stones) and cement. Ferro-cement consists of wire rod and wire mesh reinforcing and a strong cement and sand mortar. The reinforcing is arranged so that it lies just below the surface of the mortar, and the completed structure is a stressed skin that does not rely on a substantial keel and frame for support. In many ways G.R.P. and ferro-cement hulls are designed on similar principles. A hull is built by erecting a steel rod network and covering this with wire mesh, often three layers on each side of the wire rods. The mesh and rods should be tied together with short lengths of twisted wire. The reinforcing must be supported to prevent distortion when the wet mortar mix is applied, very often pipe frames are bent and set up on a precast keel and the reinforcing rods and wire mesh are fixed to this. The frames may be built into the boat or they may be removed after the mortar has dried. With this technique, it is comparatively easy to build complex shapes that would be almost impossible with timber or steel designs. Mortar is a mixture of clean, silt-free, sharp sand and cement. A ratio of two parts of sand to one part of cement is often recommended; various agents may be added to the mix to make it easier to apply to the mesh and ensure complete penetration of the spaces within the reinforcing. A relatively dry mortar must be used to reduce shrinkage on curing, otherwise hairline cracks will penetrate the dried mortar which will allow water to get through. The exact proportions of sand, cement, additives and water required will depend on the raw materials available for each situation. Expert advice should be sought and/or experiments carried out before beginning ferro-cement boat building.

Cement cures very slowly and curing continues for at least several months after initial drying. It is important that once initial setting has occurred the hull should not be allowed to dry out rapidly. If it does the full potential strength will not be developed. The hull may be covered in sacking and hosed down with water for several weeks, or it may be immersed in water. The rate of curing is temperature

dependent and rapid steam curing at a temperature of 80°C (160°F) is used by some builders; again, expert advice is essential for effective steam curing. Many ferro-cement boats have been built using mild steel rods and half-inch mesh galvanised chicken wire with perfectly satisfactory results. Current practice, however, is to specify high tensile steel rods and half-inch side square mesh netting. Local availability may restrict the choice of materials.

Many designs for ferro-cement are based on round bilges as it is only really effective as a stressed skin in curved sections. Where flat sections have been specified, supporting frames (not constructional frames) are necessary. Plates 2 and 3 show two series of photographs of construction of ferro-cement boats.

(a)

(b)

(c)

Plate 2
Stages in the construction of a small ferro-cement fishing boat in Malawi
(a) Building a small mould for a 19 ft boat
(b) Plastering after covering the mould in mesh
(c) Removing mould from hull

Ferro-cement hulls are durable and, from experience to date, have a good working life expectancy. They can be built from readily available material with unskilled labour (in a boat building sense) as long as there is adequate supervision and instruction. The hulls are not liable to attack by marine borers and are immune from attack by the rot organisms that attack wooden boats. Ferro-cement is heavier, per unit volume, than other boat building materials. However, as these boats are built on a stressed skin basis, they do not require the substantial frames that, say, larger wooden hulls have. It has been suggested that ferro-cement can compare favourably as regards weight with wooden boats 7.2 m (30 ft) long and above. As has already been stated, weight may not be a disadvantage with a work boat if it is necessary to carry ballast, providing that the upper parts (top sides) are not unduly heavy. One major disadvantage with ferro-cement hulls is the susceptibility to impact damage. However damage is generally localised around the point of impact and the shattered mortar is normally held by the reinforcing mesh which reduces the rate of leakage. Repairs are simple, easy and quick and can be undertaken with unskilled labour. With a wooden boat, impact damage tends to affect the surrounding areas and repairs may be lengthy and demand skilled labour.

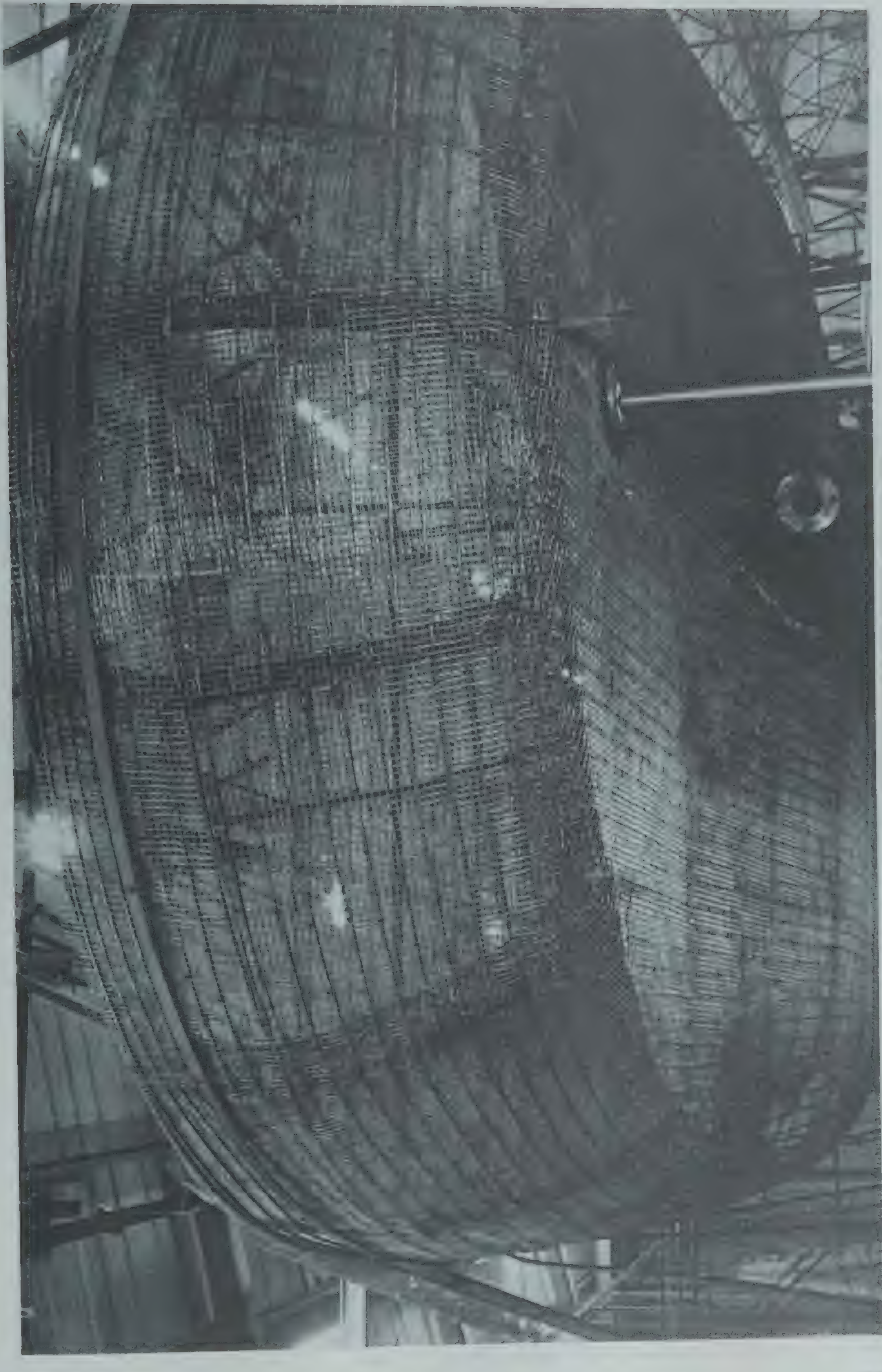


Plate 3a
Photograph showing a 60 ft hull ready for casting

Plate 3b
View looking into engine room showing engine beds and webs of 55 ft F.R.V. 'Caranx'

Plate 3c
55 ft F.R.V. 'Caranx', built in 1974 by Windboats of Wroxham

Ferro-cement is a relatively new boat building material and discussion still continues on methods and standards for construction.

FASTENINGS

In any form of boat construction various parts of the structure will require to be fastened (fixed) together. The fastening must be strong, durable and not liable to deterioration. Untreated mild steel or iron is not often used in boats as it is liable to rusting and may rapidly lose strength. Boat building nails and screws should be made of galvanised steel, stainless steel or non-ferrous materials such as copper, brass or bronze.

Nails

Where possible a nail should be clenched, i.e. the point turned over so that it is less likely to pull out (Figure 34).

Copper rivets

Often used in wooden boat building, a copper nail is pushed through the timbers to be fastened together, a rove (washer) is slipped over the end of the nail, which is cut off and then spread out to securely hold the washer (Figure 35).

Screws

Screws should be fitted into properly drilled clearance holes, they will not give maximum grip if forced straight into timber and may cause the timber to split. If clearance holes are not used the screws are likely to break when being screwed in (Figure 36).

Rivets

Rivets may be used to fasten steel or aluminium pieces together. In the past the plating of steel ships was riveted together, today welding techniques have largely replaced riveted construction (Figure 37)

Adhesives

Adhesives or glues are widely used in the boat-building industry and the traditional wood glues prepared from natural products have largely been replaced by modern synthetic adhesives. A very wide range of adhesives are now available for almost every conceivable application.

PAINTING

All boats, with the possible exception of those constructed from G.R.P. or aluminium, require painting to protect the surface, aid cleaning and improve appearance. Anti-fouling coatings are normally applied to most hulls below the water line to prevent the growth of marine organisms. A wide range of paints is available and selection of the right type for the job is important. Special priming paints are essential for wood and metal surfaces if the finishing coatings are to securely adhere to the surface. Advice should be sought from an experienced boat-builder or a paint manufacturer if any problems arise. When repainting a boat it is essential that the existing surface is thoroughly cleaned and roughened with glass paper before repainting and any loose or flaking old paint should be removed. If the boat has been repaired and bare wood or metal is exposed this should be coated with a suitable primer before any paint is applied.

In the tropics the topsides of a boat should be painted in a light colour to reflect as much of the heat of the sun as possible. If a dark colour is used the deck will become very hot and the temperature below deck will increase.

Figure 34
Clenched nailing

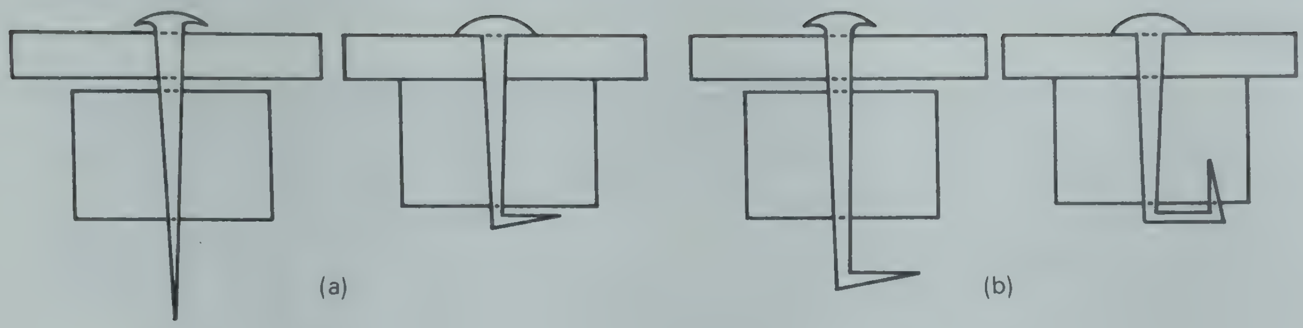


Figure 35
Copper riveting

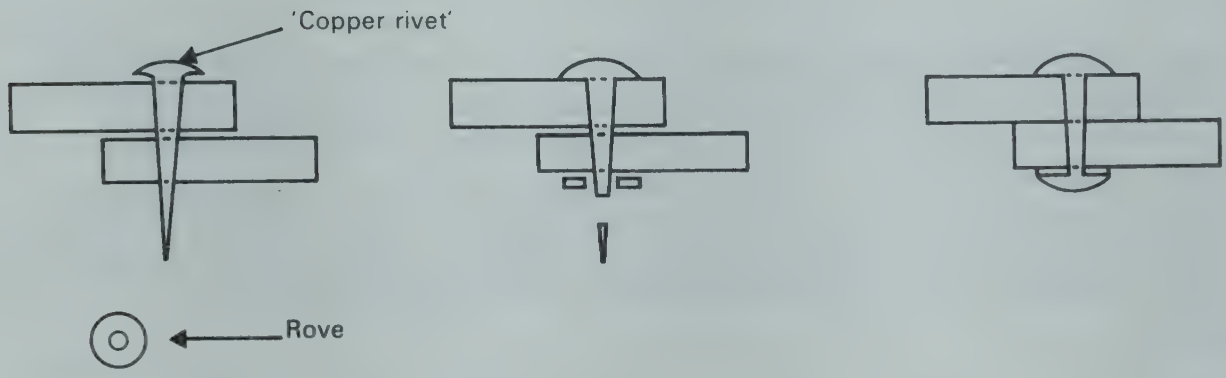


Figure 36
Wood screws

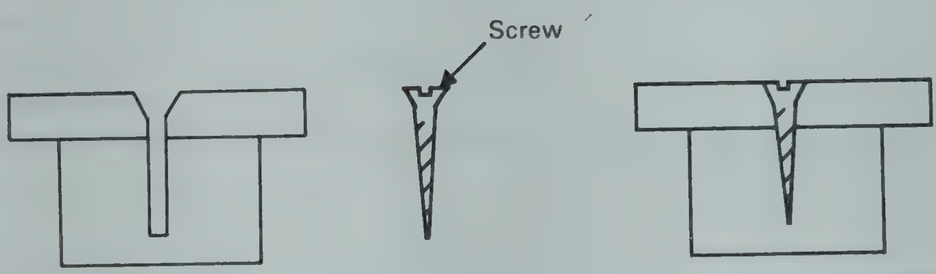
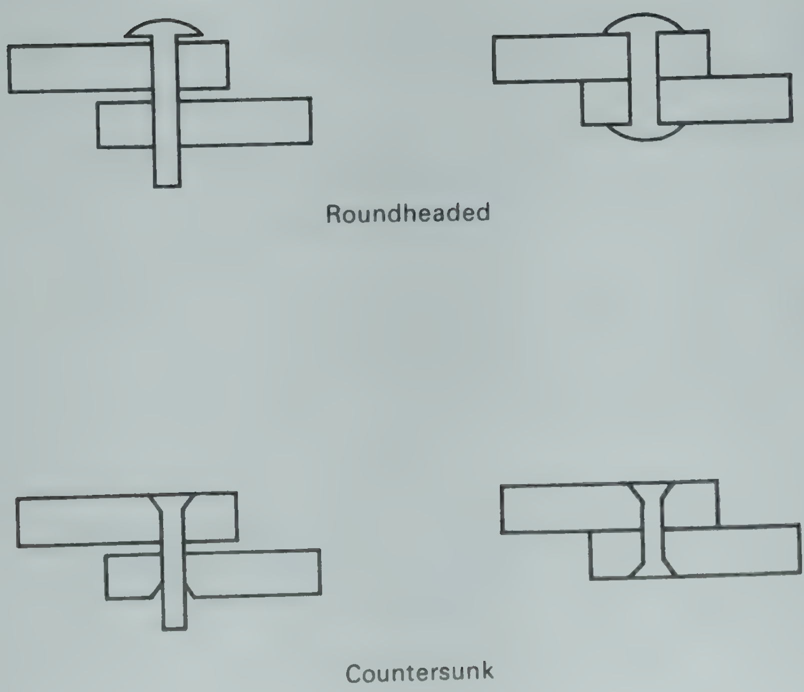


Figure 37
Rivets



REPAIRS

Many small repairs can be carried out to timber, G.R.P. and ferro-cement boats by the owner or a local craftsman and do not need skilled personnel or specialist facilities.

Impact damage to G.R.P. or ferro-cement hulls is usually localised and repairs are relatively easy. With G.R.P. the damaged area is cut away until the surrounding material is sound and undamaged. The hole is backed with a taut sheet of plastic or similar material and the hole is filled in. With a small hole, a proprietary resin based filler is applied so that the surface is slightly raised above the line of the hull. When dry the resin is sanded down to follow the hull profile. With larger holes it will be necessary to repair using glass fibres, usually in a matt form, and a resin filler, to retain the original strength of the hull. The glass fibres are kept within the line of the hull so that a clean, uniform surface is obtained when the repair is sanded down.

Repairing ferro-cement hulls follows along similar lines to that for G.R.P. A dented rather than punctured hull may be repaired by breaking out the damaged mortar, cleaning the wire mesh and replastering the hole. An epoxy-resin adhesive may be used to strengthen the bond between the old and new mortar. In more extensive holes where the reinforcing has been damaged it is necessary to cut back the mortar surrounding the hole until an area of undamaged wire is exposed. New reinforcing can then be wired into position with a substantial overlap before the hole is re-plastered.

Impact damage to wooden hulls is not normally localised and damage may extend for some considerable distance away from the point of impact. Repair will involve removing timber from the damaged area and refitting new planking or frame pieces, depending on the extent of the damage. For anything other than very minor repairs the services of a skilled carpenter or boat-builder are required. If the boat owner has any doubts about undertaking the repair himself he should seek the advice of a qualified and experienced boat-builder.

Materials for boat-building will gradually change over the years. The ways in which traditional materials are used will change as new constructional methods and modern fastenings are developed. New materials, such as ferro-cement, may come into more general use in the fishing industry. Cement reinforced with glass fibre has been used to build pontoons, but, as far as the authors are aware, boats in this material are not available commercially. Carbon fibres developed to reinforce jet engine turbine blades, have been used with G.R.P. construction in areas of the hull subjected to great stress.

FISHING BOAT TECHNOLOGY – DEFINITIONS

A range of technical terms are used to describe the parts and types of fishing boats. Listed below are some of the terms frequently used in describing boats.

Aft	(stern) the rear section of a boat.
Amidships	the centre section of a boat.
Ballast	heavy material placed in the bottom of a boat to increase stability.
Beam	
(a)	the width of a boat
(b)	timber or metal member supporting other structures, e.g. a deck beam supporting the deck planking.
Bilge	the nearly horizontal part of a ship's bottom, bilgewater is foul water that collects in the bottom of a boat.
Boom	spar attached to the mast, one end of which stretches the foot of a sail, or to hold fishing gear over the side of a boat, e.g. shrimp trawlers often fish two large nets the warps of which are held over the side by booms.
Bow	the front part of a boat or ship.
Bridge	a platform across a ship which is the navigation control centre.
Capstan	revolving barrel for winding cable. Can be manually or power operated.
Carvel	type of construction for wooden boats in which the planking is flush fitted.
Caulk	to seal joints between timbers with a waterproof filler, e.g. pitch.
Chine	the line at which the side and bottom of a flat or V-bottomed boat meet.
Deck	floor layer of a boat or ship. Very small boats are not usually decked, medium-sized fishing boats normally have a single deck, the main deck. Large ships may have decks at several levels.
Deckhouse	a room erected on the deck.
Depth	the height of a boat from the main deck level to the keel.
Draught	vertical measurement of the hull below the water level.
Engine bearer	timber or metal member supporting engine, which spreads the weight over a larger area of the hull.
Fastening	screws, nails or bolts holding the parts of a boat together. Very often copper, brass or galvanised steel fastenings are specified for wooden boats, as they are more corrosion-resistant than mild steel.
Fender	protective pad to prevent damage to the hull when the boat is moored to a pier, or two boats are tied together.
Ferro-cement	cement/sand matrix reinforced with steel rods and wire mesh.
Fibre glass	see G.R.P.
Fishroom	that part of the hold reserved for the storage of fish. In many cases the fishroom is insulated and may also be refrigerated.
Forecastle	space below deck in the forward part of a ship, often used for crew's accommodation.
Forward (bow)	the front part of the ship.
Frame	wood or metal structure which forms the shape of the hull and supports the planking or plating.
Freeboard	the height of the edge (gunwhale) of a boat above the water.
G.R.P. (Glass reinforced plastic)	hard plastic matrix re-inforced with glass fibres.
Gunwhale	the top edge of a boat's hull.
Hatch	an opening in the deck to the hold space, e.g. the fishroom hatch.

Head	this is a nautical term for toilet or WC.
Helm	steering mechanism.
Hog	a timber forming the keelpiece and lower planking of some small boats.
Hold	the main storage area below deck.
Hull	the body of a ship.
Keel	the lowermost longitudinal timber on which a ship's framework is built.
L.O.A.	length overall.
Mast	vertical wood or metal structure fixed onto, or through, the deck, provides support for sails, booms and lifting gear.
Plimsoll line	symbol painted on the side of a ship indicating the maximum loading marks for fresh and salt water.
Port side	the left-hand side of a ship looking forward.
Propeller	a revolving shaft with blades that push or pull the boat through the water.
Rowlocks	Y-shaped pieces of metal which act as a fulcrum for oars on the side of a boat.
Rudder	a flat sheet hinged to the stern of a boat for steering with.
Sacrificial electrode	a small block of zinc attached to the underside of a hull which is designed to prevent, or reduce, galvanic action on the metal parts of the hull below water. The electrode is corroded away and requires periodic replacement.
Samson post	substantial wood or metal post fitted in a vertical position in the fore part of a boat. Used for attaching heavy mooring or towing ropes.
Shackle	a device for joining two things together. Very often a D-shape, the straight side being removable on a threaded housing.
Sheet	a rope used to move or hold a sail in the required position for sailing.
Spar	wood or metal pole used to spread sails or part of lifting gear.
Spring	
(a)	to come open, i.e. for a boat to spring a leak when the planks separate.
(b)	a term applied to a mooring rope.
Starboard	the right-hand side of a boat looking forward.
Stem	the vertical or near vertical piece of timber or steel at the front of the hull to which the planks or plates are attached.
Stern	the rear part of a boat or ship.
Strake	a continuous strip of timber running along the side of a boat or ship. Very often a 'rubbing strake' is fitted over the planking just above the waterline to prevent damage to the main hull timbers when moored against a pier.
Thwart	a plank of wood built across an open boat that serves as a seat for paddlers, rowers and passengers.
Tiller	a long piece of wood or metal fixed to the top of the rudder used as a lever to control the steering.
Transom	flat or nearly flat rear part of a boat.
Waterline	the normal level to which the hull of a boat is submerged under the water.
Whaleback	a raised deck fitted in the bow of a ship.
Winch	a machine for pulling in ropes, e.g. a trawl winch is used to haul in the trawl net ropes or wires.

REFERENCES AND SUGGESTIONS FOR FURTHER READING FOR CHAPTER 3

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Chapter 4

Engines

In all internal combustion engines a compressed mixture of fuel and air is fired (ignited). Ignition causes the fuel to burn rapidly, the heated gases expand and create pressure, which restricted by the cylinder walls, forces the piston down.

In most internal combustion engines the energy provided by the fuel burning is converted into a reciprocal motion of the piston within the cylinder. By the arrangement of a connecting rod (from the piston to the crankshaft) and eccentric (off centre) crankpin on the crankshaft the energy is converted to a rotary motion which can easily be used to drive equipment e.g. boats, vehicles, pumps and generators (Figure 38). As power or energy impulses can only occur on one stroke of the piston, a heavy flywheel is fitted to the crankshaft to provide sufficient momentum to return the piston to the top of its stroke ready for the next power impulse. The mass of the flywheel also smoothes out the power impulses on an engine that is running and reduces the fluctuations in power output. A heavy flywheel is obvious on most slow speed single cylinder engines. With multicylinder and high speed engines much smaller flywheels can be used to provide an acceptably smooth power output.

Many people think that the compressed fuel/air mixture explodes when ignited, in fact, it burns very rapidly. If it does explode or detonate a slight tinkling noise can be heard which is called 'pinking'. This can be heard on a petrol engine run on too low a grade of fuel or if the ignition timing is too advanced. If the fuel/air mixture detonates, there is an almost instantaneous and extreme rise in pressure which places a sudden and heavy strain on all the working parts of the engine, particularly the piston and connecting rod bearings. If, however, the fuel burns at a controlled rate, after ignition, the increase in pressure is more gradual and does not reach such high levels as the piston will already be moving downwards. This obviously throws less strain on the moving parts of the engine and produces the power far more smoothly.

Internal combustion engines available commercially are of two basic types, those operating on the two-stroke cycle and those operating on the four-stroke cycle, a cycle being the sequence of operations which, when complete, returns the engine to the starting condition. A stroke is a movement of the piston in a single direction, i.e. from the top to the bottom of the cylinder or from the bottom to the top.

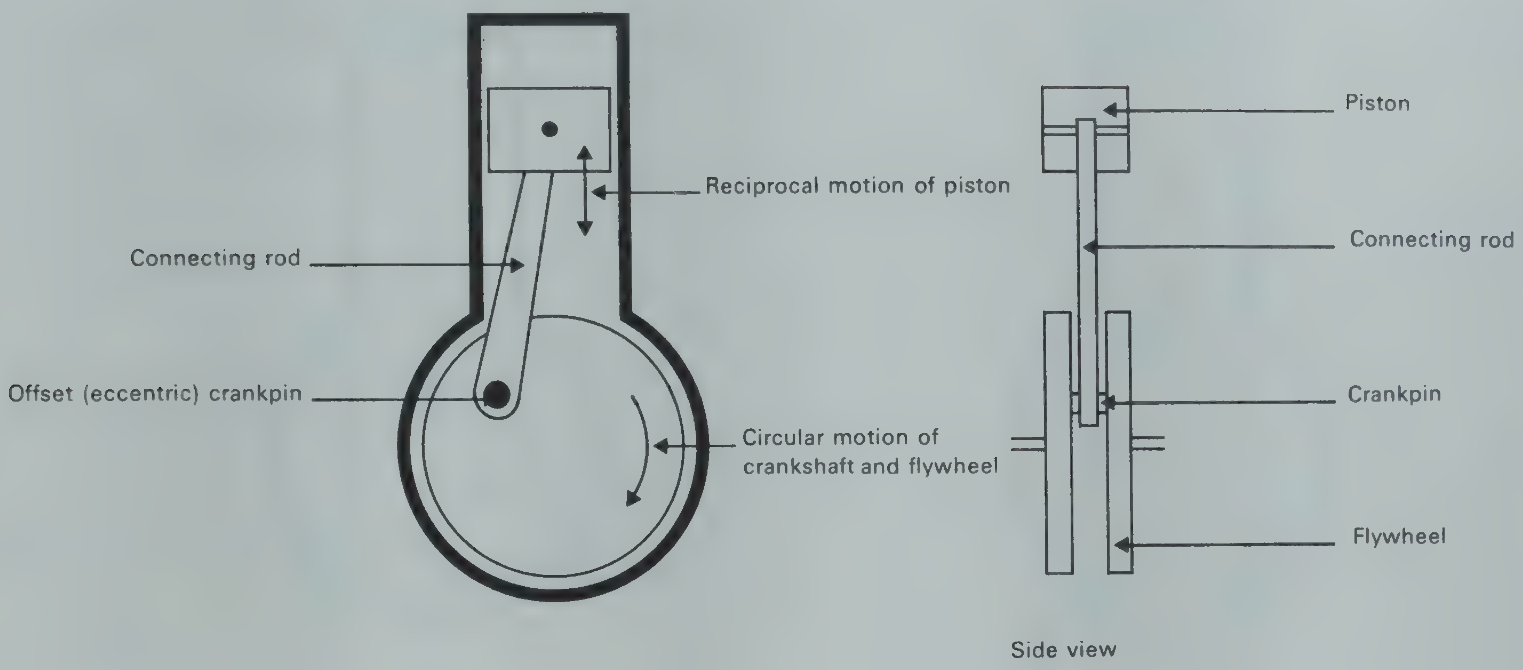
FOUR-STROKE CYCLE

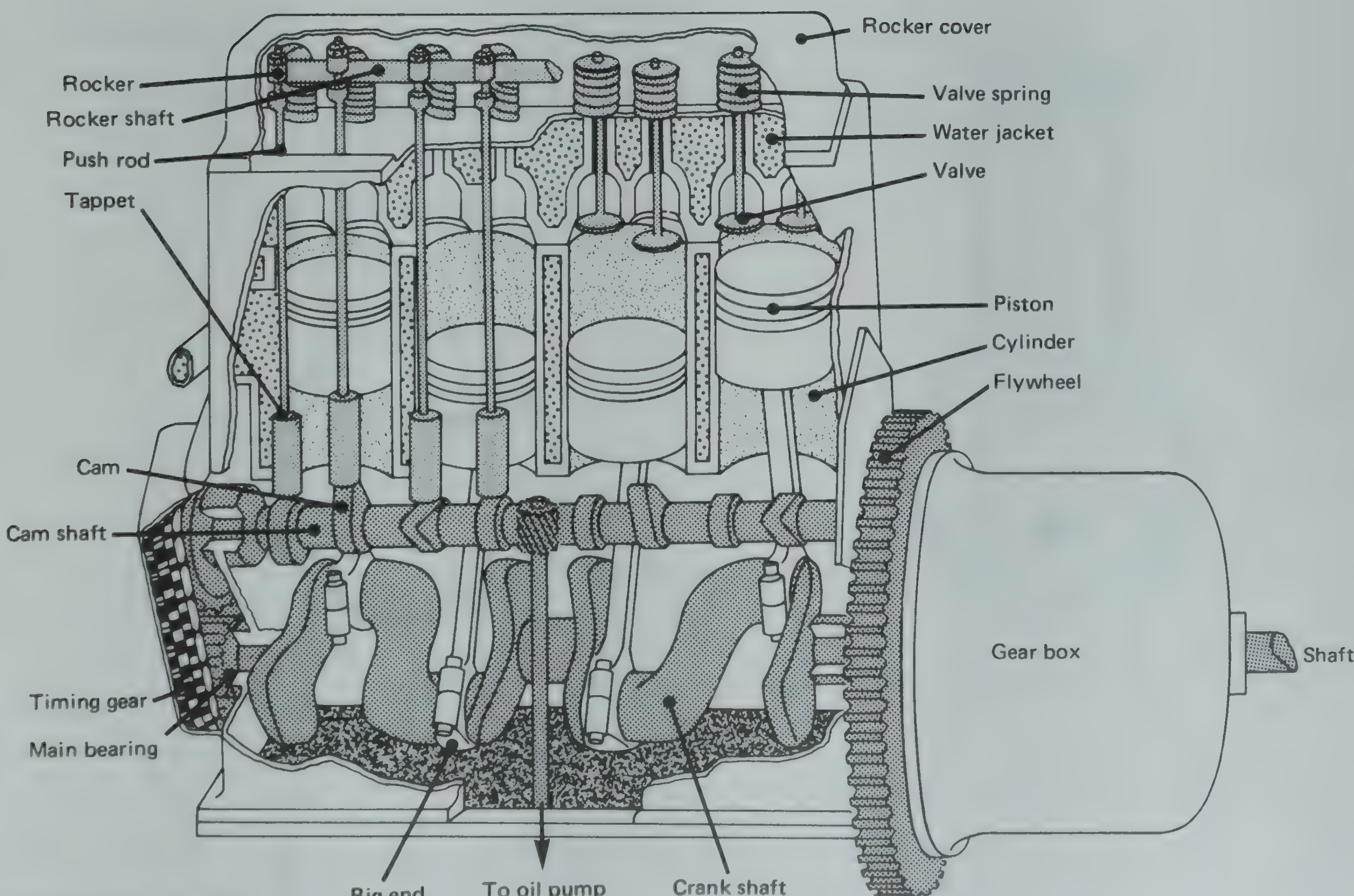
The four-stroke cycle is described first as it is easier to separate its component parts. It works as follows in a petrol engine (Figure 39).

Stroke 1 the piston moves downward sucking the fuel/air mixture in through the open inlet valve.

Stroke 2 the piston moves upward compressing the fuel/air mixture. Just before the piston reaches the top of its stroke, the fuel is ignited by passing a spark across the points of a sparking plug that protrudes into the combustion chamber.

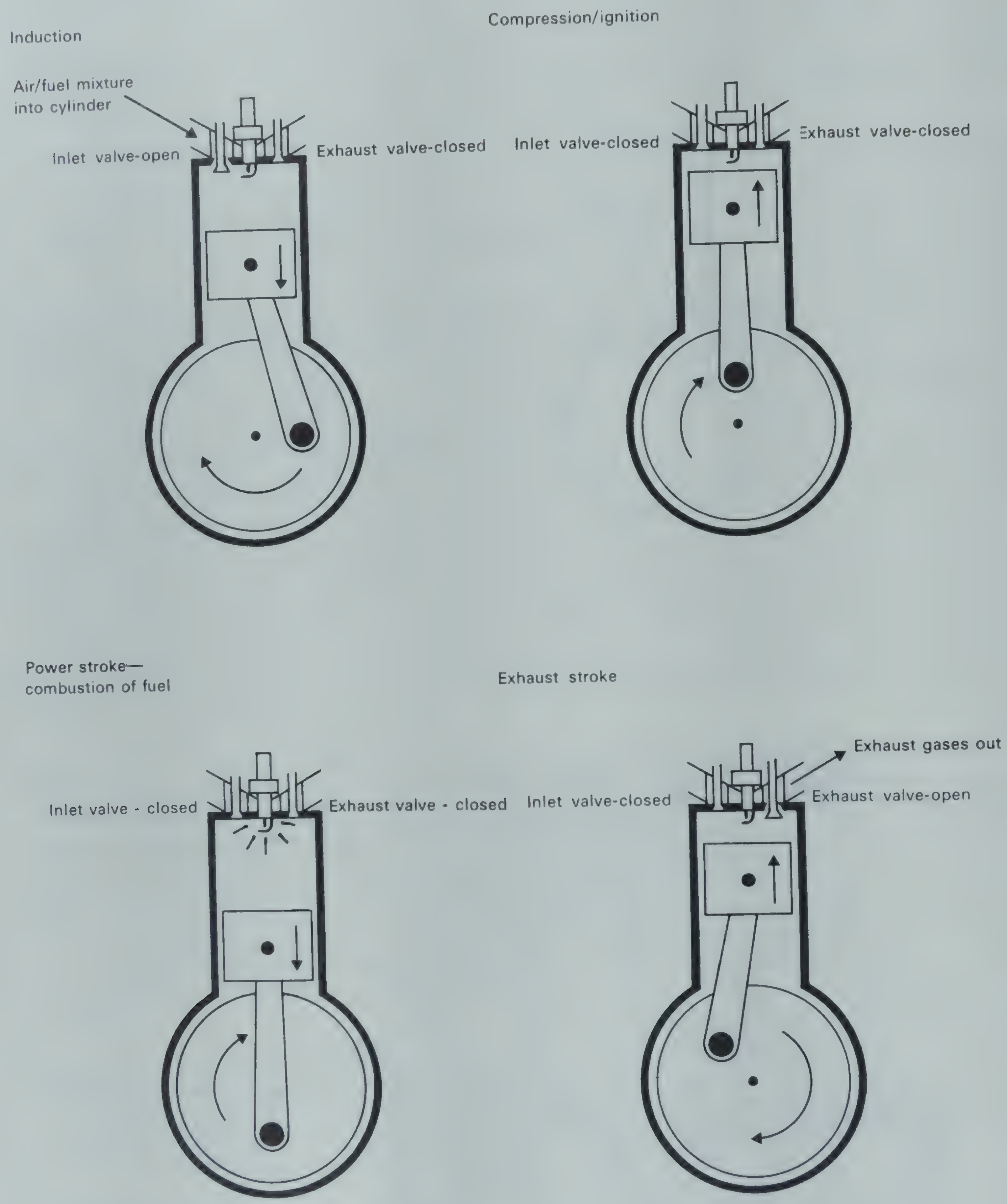
Figure 38
Internal combustion engine — principles of operation





Four cylinder engine

Figure 39
The four-stroke cycle



Stroke 3 the burning fuel/air mixture forces the piston downwards.

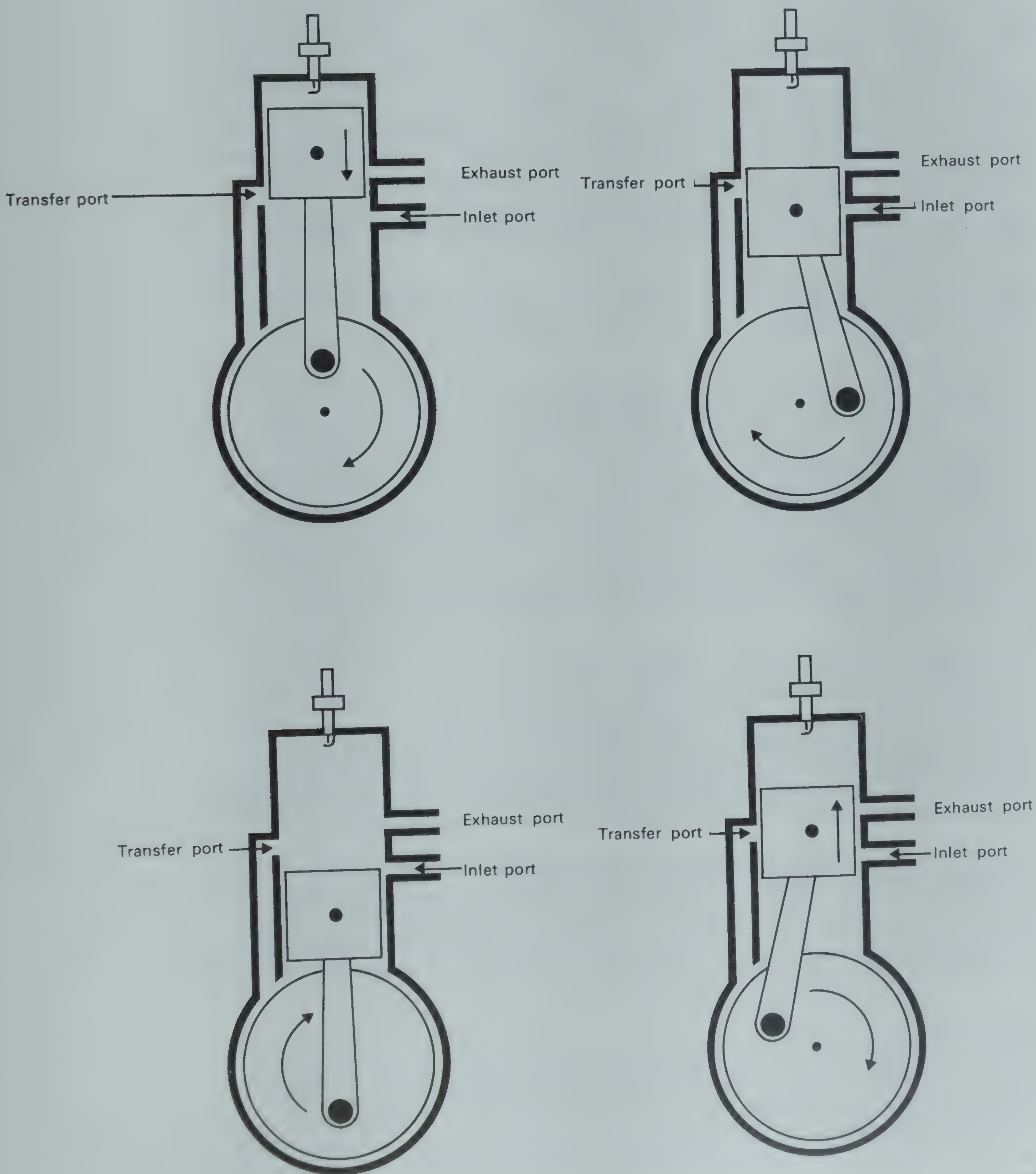
Stroke 4 the piston moves upwards expelling the burned mixture (exhaust gases) through the open exhaust valve. The piston is now at the top of the cylinder and ready to begin the cycle over again.

Four-strokes of the engine comprise two complete revolutions of the crankshaft.

TWO-STROKE CYCLE

In a two-stroke engine, the cycle is completed in two strokes of the piston, one upward, one downward, which comprises one revolution of the crankshaft. Although apparently simpler as the cycle is completed in two rather than four strokes, it is in fact more complex as each stroke combines more than one function. The two-stroke engine works as follows (Figure 40).

Figure 40
Crankcase - scavenged two-stroke engine



Stroke 1 the piston is moved downwards by the force of the burning fuel/air mixture. As it moves downwards, the exhaust port is opened and the gases from the burned fuel are led away from the cylinder through the exhaust port or valve.

Stroke 2 the inlet port is opened at, or just before, the beginning of the upward movement of the piston and a fresh fuel/air mixture is introduced into the cylinder. This mixture is compressed as the piston moves upwards and ignition occurs just before the piston reaches the top of the stroke. Before all the burned fuel/air mixture leaves the cylinder, the next charge of fresh mixture is already entering and it may in fact help to expel the last remnants of the exhaust gases.

Unlike a four-stroke engine, the fuel/air mixture is not fed directly into the cylinder but passes through the crankcase first. As the piston travels upwards it creates a negative pressure or suction in the crankcase spaces which sucks in the fuel/air mixture. The opening, or port, into the crankcase is controlled by the piston in many engines, although rotary disc valves on the crankshaft are used in some. On the downward stroke the mixture in the crankcase is compressed, partway down, the transfer ports which are controlled by the piston crown are opened and the fuel/air mixtures moves from the crankcase into the cylinder. For a given capacity, a two-stroke is less efficient than a four-stroke engine and has a higher fuel consumption. The two-stroke engine has fewer moving parts and, as a consequence, fewer points that can be wrongly adjusted. In a simple two-stroke engine, the piston controls the opening and closing of the inlet, transfer and exhaust ports, the timing of which is determined in the design stage, and it is not easy to alter later. In a four-stroke engine, however, it is not difficult to wrongly adjust the inlet and exhaust valve clearances or even alter the basic valve timing.

Ignition of the compressed fuel/air mixture is by two basic methods, regardless of whether the engine operates on the two or four-stroke cycle.

1 *Spark ignition.* A spark is passed across the points of a sparking plug just before the piston reaches the top of the compression stroke. The exact timing of the spark in relation to the top of the compression stroke can be varied to suit the operating speed of the engine, the quality of the fuel and the mechanical conditions of the engine. For engines that run within a narrow working speed range, fixed ignition timing may be suitable. For engines that run over a wide working speed range, facilities may be fitted to vary the ignition timing. Automobile engines are examples of engines where a wide operating speed range is essential. Variation of the ignition timing may be manually or automatically controlled. All petrol and paraffin engines use the spark ignition system.

2 *Compression ignition.* Compressing any gas causes an increase in temperature and if the rise in temperature is sufficient, ignition of the fuel/air mixture will occur. All modern diesel engines operate on this principle. In the diesel engine, unlike the petrol engine, only air is drawn into the cylinder on the intake stroke, this is compressed on the next upward stroke causing a rapid and great increase in temperature. Fuel is injected into the hot compressed air in the form of a fine spray near the top of the compression stroke and ignition occurs. Diesel engines are available that operate on the two-stroke and four-stroke principles.

To develop the high temperature necessary for ignition in diesel engines, high compression ratios are needed. The compression ratio is the ratio between the volume of the cylinder, including the combustion chamber with the piston at the bottom of the stroke and at the top of the stroke. Most diesel engines operate with a compression ratio of between 15:1 and 20:1, whereas petrol engines have a compression ratio of between 6:1 and 10:1.

Diesel engines are generally more economical to operate than petrol engines and most medium-sized and almost all large marine engines are of this type. Each basic type of engine has advantages and disadvantages and selection of any one type for a particular application will depend on the operating conditions. In developing countries, one very important consideration must be the servicing facilities available to the user. Good stocks of spare parts and skilled mechanics familiar with and,

preferably, trained on the maintenance and repair of the engine should be available. For the average fisherman, there is little sense in being the owner of the only engine of that manufacturer in the country. In many developing countries where boat mechanisation schemes are being introduced the adoption of a single engine type from one manufacturer has advantages as it is easier to arrange for adequate stocks of spares to be held and for mechanics to be trained. Obviously the engine chosen should be suitable for the job demanded of it under the local operating conditions. If several sizes of engine are needed it may be possible to choose a manufacturer where many parts are common to a range of engines, in some cases manufacturers produce a range of engines of different power outputs or made with different numbers of cylinders of a basic type, i.e. one-cylinder, 8 hp; two-cylinders, 16 hp; three-cylinders, 24 hp.

Listed below are some of the advantages and disadvantages of the basic types of engines.

Diesel

Advantages
1 Low relative fuel consumption.
2 Cheap fuel.
3 Reduced fire risk with fuel.
4 Reliable.
5 Long intervals between major overhauls.

Disadvantages
1 High weight.
2 Higher initial cost.
3 Noisy.
4 Large size.
5 Skilled servicing essential.

Petrol

Advantages
1 Lower initial cost.
2 Light weight.
3 Readily available fuel.
4 Quiet.
5 Compact.
6 Mechanics experienced with petrol engines are available almost everywhere.

Disadvantages
1 Fuel constitutes a serious fire risk.
2 More frequent service intervals.
3 Less reliable, particularly ignition system.
4 Fuel expensive.
5 High relative fuel consumption.

If selection of an inboard engine is to be made on the grounds of reliability, long intervals between servicing, economy of operation, and safety, a diesel engine would be the obvious choice. If initial cost, ease of servicing, light weight and small size are important considerations, then a petrol engine may be preferred.

Outboard engines are used to power a whole range of fishing craft, particularly the smaller sizes. Attaching an outboard engine requires only a simple bracket and many traditional canoes and small boats around the world have been mechanised with outboard engines. Almost all outboards are petrol engines and the majority of these are two-stroke. The two-stroke cycle outboard engine is markedly less efficient than an inboard engine in terms of power output per unit of fuel consumption and has a shorter working life.

Under certain conditions, an outboard engine may be the only sensible choice, even after giving due allowance to its low efficiency and shorter working life. Many small canoes and boats could not be fitted with an inboard engine unless major modifications to the structure of the hull were carried out. The following table gives comparative information on engine types:

Engine	Fuel consumption (hp/hour)	Lubrication oil consumption. Percentage of fuel	Life expectancy (years)	Maintenance, percentage of cost
Diesel	0.45	2	7	12
Petrol (inboard)	0.70	3.5	5	15
Outboard	0.85	5	3	18

(Kvaran, 1964)

ENGINE MAINTENANCE

Any engine must be looked after if it is to give good performance, be reliable, and have a long life. Maintenance can be defined as all the activities undertaken to keep an engine in good running order. Various other terms are used to describe certain types of work undertaken to keep engines in good running order. Kvaran (1964) has defined the following terms in the context in which they are normally used.

Servicing – regular and routine attention to reduce the rate of wear of the parts of an engine. Generally restricted to minor adjustments and changing of lubricants and cleaning or replacing fuel or oil filters. Very often carried out by the crew on the boat and does not always require the attention of a skilled mechanic.

Overhauling – removal and repair or replacement of worn parts.

Top overhaul – cylinder head and combustion chamber only.

Bottom overhaul – crankshaft, its associated bearings and pistons.

Repairing – work done to cure a fault. Depending on the size of the fault it may or may not be possible to do it on the boat.

Reconditioning – bringing a complete engine or parts of one back into a similar condition to that of a new engine.

Inspection – checking an engine by a qualified engineer. Inspection may be necessary to ensure that the normal maintenance programme is being followed, to identify possible faults and to report on the general condition of the engine. When buying a second-hand engine, it may be advisable to have a qualified engineer, experienced with marine engines, inspect it. The cost of inspection will be more than justified if it identifies any major faults, and indicates the work required to bring the engine into good running condition.

The manufacturer always produces an owners handbook or service manual, for each engine. If the instructions in this are followed, there should be trouble-free operation and any minor breakdowns which result from poor maintenance should be avoided. Although manufacturers may prepare handbooks in several languages, very many of the minor languages spoken would not be printed. If you cannot obtain a handbook in a language you understand, contact the main agents for the engine in your country and they should be able to provide a translation or the essential information. If a handbook is translated into several languages, the precise meaning of instructions may be lost because of shift of emphasis or poor translation.

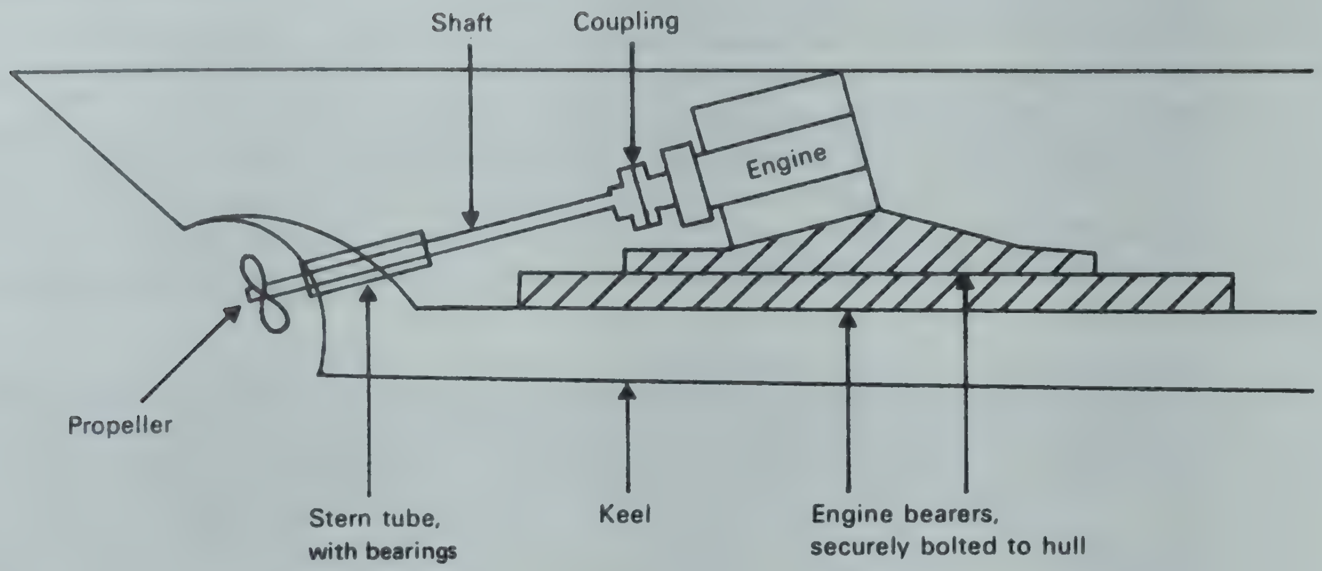
Routine servicing of a small fishing boat engine does not require highly skilled mechanics. The crew should be able to carry out this task with a minimum of training. Periodic inspection to check that the servicing is being carried out is necessary with a fleet of boats and hired crews. Owner/skippers should be made aware of the benefits of a sensible maintenance routine and the need to carry this out regularly. In all cases, a log book should be kept recording the hours the engine runs, oil added and the maintenance undertaken. A record of the fuel taken on board should also be maintained. If a detailed log is kept it is possible to check on the economics of operation, arrange major overhauls in advance, not wait until the engine breaks down and also to obtain a good idea of the overall condition of the engine.

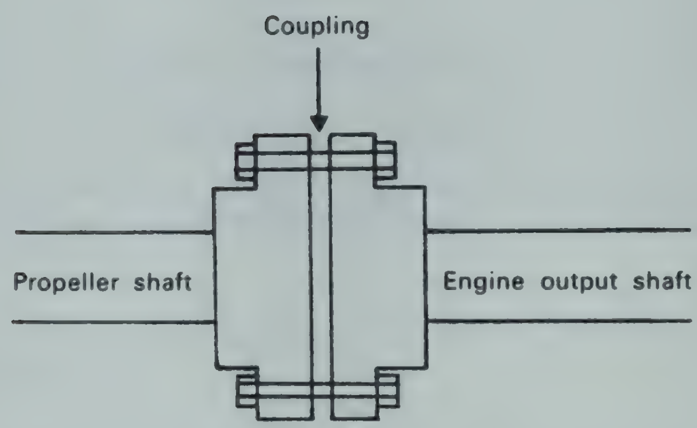
The theory of operation and the engines so far described have all been of the basic types and many modern engines currently in use are more sophisticated and differ from the basic engine. Many modern engines are fitted with super-chargers or turbo-chargers which increase the power output of the engine without making it much bigger. Regardless of such modifications to the engine, the basic principles of operation, servicing and maintenance apply. So long as the manufacturers handbook is followed carefully few problems should arise in situations where the fishermen are already used to looking after simple basic engines. But, when a project to motorise fishing vessels for the first time is considered it is best to use only simple engines. This makes it easier for the fishermen to learn to operate and maintain the new equipment.

The installation of an engine in a boat, whether inboard or outboard, must be carefully carried out if the engine is to provide efficient propulsion and have a long service life. An outboard engine must be securely clamped to a substantial bracket built onto the boat, which, to some extent, may be situated in a part of the boat that is suitable for the local operating conditions and does not interfere with the handling of the fishing gear; several of the alternatives were discussed in Chapter 2.

An inboard engine can only be mounted in a fore and aft position in the bottom of the boat (Figure 41). As the engine and propellor shaft are rigidly fastened together it is extremely important that the engine is mounted on substantial bearers and accurately aligned with the shaft. If the engine is out of alignment, bearing failure and excessive vibration are likely. The engine bearers should spread the weight of the engine over as large an area of the hull as possible. If an engine and shaft are fitted to a boat that is out of the water the alignment must be checked as soon as the boat is put in the water as the hull is often distorted when hauled out of the water. Shaft alignment should be checked regularly. An inboard engine installation may not be suitable if fitted to a hull that is too flexible. It is advisable to have a boat designed to take a particular type of engine of the required power output.

Figure 41
Inboard engine installation





The alignment of the engine should be adjusted by packing thin metal plates (shims) under the engine mountings until the faces of the coupling are perfectly aligned. The engine should then be firmly bolted down to the bearers, the coupling alignment checked and then securely fastened.

REFERENCES AND SUGGESTIONS FOR FURTHER READING FOR CHAPTER 4

KVARAN, E. (1964) In: *Mechanisation of small fishing craft.* London: Fishing News (Books) Ltd., 112 pp.

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Appendix

Units of measurement

Some of the readers of this report will be used to working in British units, some in Systeme International d'Unites (SI units). Some countries are changing from British to SI units. The most commonly used units are given in both systems and conversion factors given where these are likely to be useful.

In the SI system the following prefixes are commonly used.

Kilo (k)	Unit x 1,000
Hecto (h)	Unit x 100
Deca (da)	Unit x 10
Deci (d)	Unit x $\frac{1}{10}$
Centi (c)	Unit x $\frac{1}{100}$
Milli (m)	Unit x $\frac{1}{1,000}$
Micro (M)	Unit x $\frac{1}{10,000}$

Length and distance

The British unit is the yard (yd), the SI unit is the metre (m).

1 inch (in)		= 0.0254 m
1 foot (ft)	= 12 inches	= 0.3048 m
1 yard (yd)	= 36 inches	= 0.9144 m
1 chain	= 22 yards	= 20.1168 m
1 Furlong	= 10 chains	= 201.168 m
1 Land or Statute Mile	= 8 furlongs	= 1,609.3 m
1 Land or Statute Mile	= 1,760 yd = 5,280 ft	
1 UK sea mile	= 6,080 ft	= 1,853.18 m
1 SI sea mile		= 1,852 m
1 Fathom	= 6 ft	= 1.8298 m

SI units

1 kilometre (km)	= 0.6214 mile		= 3281 ft
1 metre (m)	= 3.281 ft		
1 decimetre (dm)	= $\frac{1}{10}$ m	= 0.328 ft	= 3.93 in
1 centimetre (cm)	= $\frac{1}{100}$ m	= 0.0328 ft	= 0.39 in
1 millimetre (mm)	= $\frac{1}{1,000}$ m	= 0.0033 ft	= 0.04 in

Note: A rough conversion from km to miles is obtained by multiplying by 5 and dividing by 8 e.g. 16 km x $\frac{5}{8}$ = 10 miles. Similarly a distance in miles multiplied by $\frac{8}{5}$ gives km e.g. 20 x $\frac{8}{5}$ = 32 km.

Area

British units

1 square foot	= 144 square inches	
1 square yard	= 9 square feet	= 0.836 m^2
1 rood	= 1,210 square yards	= 1,011.7m^2
1 acre = 4 roods	= 4,840 square yards	
	= 43,560 square feet	
	= 4,046.86 m^2	
1 square mile	= 640 acres	

SI units

1 are		= 100 m^2	= 120 yd^2
1 dekare	= 10 ares	= 1,000 m^2	= 1,200 yd^2
1 hectare (ha)	= 100 ares	= 10,000 m^2	

Note: 1 acre = 0.404 ha, 1 hectare = 2.471 acres.

Weight

British units

1 ounce		= 28.35 g
16 ounces (oz)	= 1 pound (lb)	= 453.6 g
14 pounds	= 1 stone	= 6.350 g
28 pounds	= 1 quarter	= 12.7 kg
112 pounds	= 1 hundred weight(cwt)	= 50.8 kg
100 pounds	= 1 central	= 45.36 kg
2,240 pounds	= 1 long ton	= 1,016.05 kg

SI units

1 gramme (g)		= 0.035 oz
1 kilogramme (kg)	= 1,000 g	= 2.205 lb
1 tonne	= 1,000 kg	= 2,205 lb

Volume (liquid measure)

British units

4 gills	= 1 pint	= 0.568 litres (l)
2 pints	= 1 quart	= 1.136 litres
4 quarts	= 1 gallon	= 4.546 litres

SI units

The unit of volume is the cubic metre (m^3) 1 cubic decimetre (dm^3) is $\frac{1}{100}$ m^3, this is referred to as one litre (l) when measuring liquids. A litre is the volume of 1 kg of water at a standard temperature and pressure.

1 decilitre	$= \frac{1}{10}$ litre	
1 centilitre	$= \frac{1}{100}$ litre	
1 millilitre (ml)	$= \frac{1}{1,000}$ litre	= 1 cubic centimetre (cc)

Note: It is useful to be able to convert volumes of water to weights and vice versa, for example:

In British units

1 gallon of water weighs 10 pounds
1 cubic foot of water weighs 62.3 pounds
39 cubic feet of water = 224 gallons = 1 ton

In SI units

1 litre of water weighs 1 kilogramme
1,000 litres of water weighs 1 tonne

Velocity (Speed)

British units

Foot per second	1 ft/s	= 0.3048 m/s
Inch per second	1 in/s	= 0.0254 m/s
Foot per minute	1 ft/min	= 0.00508 m/s
Mile per hour	1 mile/h	= 0.447 m/s

SI units

1 metre per second (m/s)	= 3.280 ft/s
	= 3.6 km/h
1 kilometre per hour (km/h)	= 0.911 ft/s
	= 0.621 mile/h

Note: The knot is one sea mile per hour

1 UK knot	= 6,080 ft/h	= 0.514 m/s
1 International knot	= 1,852 m/h	= 0.514 m/s

Temperature

Two scales are in common use, the Fahrenheit (F) scale in which the temperature of melting ice is taken as 32° F and that of boiling water as 212° F and the Celsius (C) or Centigrade scale in which the temperature of melting ice is 0° C and that of boiling water 100° C. There are thus 100 Celsius degrees between the freezing and boiling points of water and 212–32 = 180 fahrenheit degrees.

So 1° C = 1.8° F. Conversely 1° F = 0.56° C.

To convert from Fahrenheit to Celsius use the formula:

$$°C = \frac{5}{9}(F-32)$$

e.g. for 50° F, $C = \frac{5}{9}(50-32) = \frac{5}{9} \times 18 = 10°C$.

To convert from Celsius to Fahrenheit use the formula:

$$F = \frac{9 \times °C}{5} + 32$$

e.g. for 20° C, $F = \frac{9 \times 20}{5} + 32 = 68°F$.

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